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COST EFFECTIVE FIRE MANAGEMENT: THE CONCEPTUAL FRAMEWORK OF THE PLANNING PROCESS

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SUMMARY OF PROCESS AND PLAN

The Sequoia National Forest was selected as one of the two forests in the California region that would independently develop fire management planning processes that would conform to the fire management policy revision of 1978. This paper describes the development of a proposed process and a pilot study of the proposed process on the Kern Plateau unit of Sequoia National Forest. Specific examples are drawn from the study of the Kern Plateau to illustrate the use of the process.

The goal of the project was to develop and test a process that can be used to make fire management techniques cost-effective, as is directed by the new policy. The proposed planning process aims at determining the most cost-effective management strategy for each dispatch unit and fire management area, and the optimum mix of detection, prevention, initial attack,[1] and fuel management expenditures for the forest (figures 1 and 2).

The planning process has two related decision steps. The first decision, which can be preplanned and adjusted annually, is what initial dispatch to send to a reported fire. A decision to send an air attack involves large expense, while sending a single truck to investigate does not. This first decision is based on information on fuels, slope, weather, and resource values. The second decision, which is an output of fire modelling, is what suppression strategy to use, direct or indirect, if that initial dispatch fails to contain the fire. This two-step process allows flexibility in obtaining a cost-effective protection plan.

Fire Management Objectives

Broad fire management objectives come from land use planning. Specific fire management objectives for the pilot areas were determined through economic analysis, or, when detailed analysis was not possible, from an economic perspective. The processes used in the analysis are discussed in detail throughout this report, and the objectives that emerged from these are summarized in Table 1.

Prevention and Detection

Prevention objectives were divided into: 1) continued emphasis on motorized fire prevention techniques (FPT's), which is the current emphasis and which is warranted if most access is by road; 2) emphasis on foot/horse travel for FPT's, which is the current trend in recreational objectives on the Plateau, and which is warranted if the primary access

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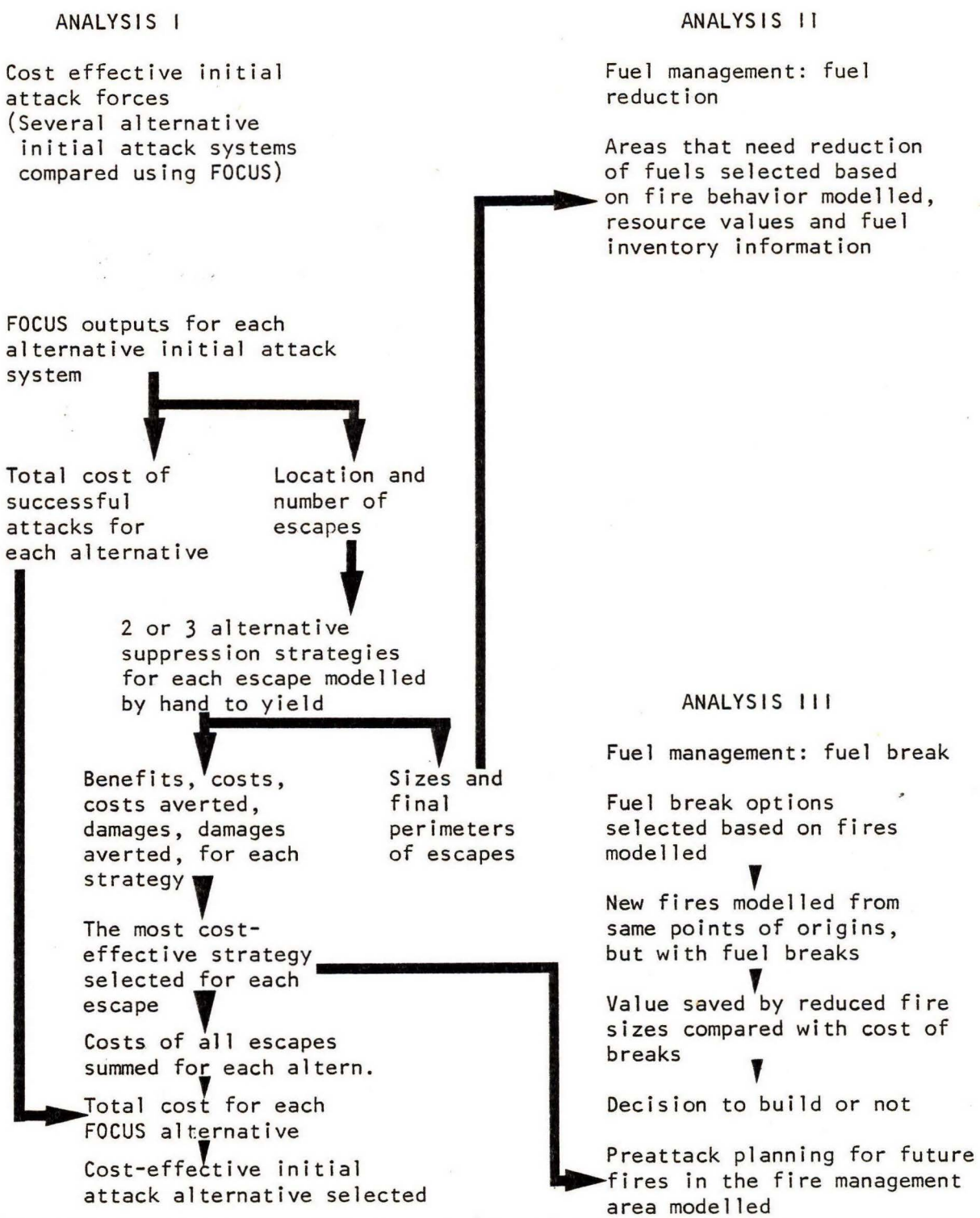
[1] A distinction is made in Figures 1 and 2 and in the remainder of this paper between initial attack, which is the action taken by forces preplanned for initial dispatch, and suppression, which is the action taken once an initial attack force has failed to contain the fire. The initial attack becomes suppression at the time that more help is requested.

STEPS IN THE PROPOSED PLANNING PROCESS
(See details in Figure 7)

STEPS	INFORMATION NEEDED
1. Determine fire management objectives	Land management objectives Cost-effective management strategy
2. Delineate fire management areas	Resource inventories
3. Break fire management areas into dispatch zones	Weather zones Fuel inventories
4. Develop a cost-effective plan for initial attack	FOCUS-selected optimal location of forces or Present location of forces
5. Model escaped fires (see details in Figure 2)	FOCUS-determined locations of probable escapes or Subjectively determined locations of probable escapes for each fire management area
6. Select best suppression strategy for each fire management area	
7. Assess fuel reduction and fuel break projects (see details in Figure 2)	Current fuel reduction and fuel break costs

Figure 1.

FLOW DIAGRAM OF THE PROPOSED PROCESS FOR SELECTING STRATEGIES.


ANALYSIS I
Cost effective initial attack forces (Several alternative initial attack systems compared using FOCUS)
ANALYSIS II
Fuel management: fuel reduction
Areas that need reduction of fuels selected based on fire behavior modelled, resource values and fuel inventory information
FOCUS outputs for each alternative initial attack system
Total cost of successful attacks for each alternative
Location and number of escapes
2 or 3 alternative suppression strategies for each escape modelled by hand to yield
Benefits, costs, costs averted, damages, damages averted, for each strategy
Sizes and final perimeters of escapes
ANALYSIS III
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Fuel break options selected based on fires modelled
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Decision to build or not
The most cost-effective strategy selected for each escape
Costs of all escapes summed for each altern.
Total cost for each FOCUS alternative
Cost-effective initial attack alternative selected
Preattack planning for future fires in the fire management area modelled

Figure 2.

FLAME

TABLE 1

FIRE MANAGEMENT OBJECTIVES AND STRATEGIES

Fire Management Area	Prevention	Detection	Initial Attack	Strategy	Suppression Allowable Burn (Ac)[6] 50th	90th	Fuel Management Reduction	Fuel Breaks
Baker	1	5	19	13	6000-12000	<8000	15	17
Basin	2	5	7	9	<3700	<8000	15	18
Beach	3	5	7	9	<1200	<6000	15	17
Brush	2	5	7	10	18000-30000	<30000	15	17
Clover	3	5	7	9	<10	<20	16	18
Curlis	3	5	7	11	<1000	<4000	15	17
Cyrus	2	5	7	9	<4000	<5000	16	17
Domelands 1	4	5	8	10	<16000	15000-20000	N/A	18
Domelands 2	4	5	8	10	30-400	300-400	N/A	N/A
Golden Trout	4	5	8	12	<13000	<4000	N/A	17
Horse	2	5	7	9	<100	<20	16	17
Lookout	4	5	19	12	3000-18000	<3000	16	17
Rim	1	5	19	13	6000-12000	<8000	15	17
Smith	2	5	7	14	1000-2000	2000-3000	15	18
True	2	5	7	14	<700	300-700	16	18

[1] Emphasis on motorized fire prevention technicians (FPT), high priority.
[2] Emphasis on motorized FPT's, low priority.
[3] Emphasis on foot/horse FPT combined with motorized FPT, low priority.
[4] Emphasis on foot/horse FPT's, low priority.
[5] Lookout's goal to report fires first, air detection used after lighting activity and automatic lightning detection as goals.
[6] This allowable burn figure is the allowable burn acreage that would be the target for any one escaped fire. Table 6 summarizes the allowable burn for a fifty year time period.
[7] When adjective rating is low, use modified initial attack; when medium, use modified initial attack; when high, use full initial attack capabilities (See Table 3).
[8] When adjective rating is low, use observation only; when medium, use modified initial attack; when high, use modified initial attack (See Table 3).
[9] Direct attack with 50th or 90th percentile weather conditions.
[10] Indirect attack with 50th or 90th percentile fire weather conditions.
[11] Direct attack with 50th percentile fire weather conditions, and combined direct and indirect attack with 90th percentile conditions.
[12] Indirect attack with 50th percentile fire weather conditions, and combined direct and indirect attack with 90th percentile fire weather conditions.
[13] Indirect attack with 50th percentile fire weather conditions, and direct attack with 90th percentile conditions.
[14] Combined direct and indirect attack for both 50th and 90th percentile fire weather conditions.
[15] High priority to reduce fuel through burning and to verify burn cycles in timber areas.
[16] Low priority to reduce fuel through burning.
[17] High priority to construct fuel breaks.
[18] Low priority to construct fuel breaks.
[19] When adjective rating is low, use modified initial attack; when medium or high, use full capability initial attack.

is by trail, and 3) combined use of motorized FPT's and foot/horse FPT's, which is warranted if some parts of the fire management area are not accessible by vehicles. Priority was given to FPT operations by reviewing the location of man-caused fires (See Figure 13, p 65).

Detection objectives include the previous ones and a new system: 1) Lookouts are the primary agent used to detect fires, 2) Air detection is used only after lightning activity or after heavy use periods,and 3) Automatic lightning detection through cooperation with the Bureau of Land Management's program to automate lightining detection.

Reduction of energy use should become a priority goal in all management activities, particularly in prevention and detection. Implementation of new technology should be balanced against the use of human labor, which has associated social benefits.

Dispatching and Initial Attack

In examining the present dispatch system, a vegetation map was first used to evaluate the possibility that the weather stations being employed on the Plateau were improperly placed for fire weather observation on the Plateau. Although the Bald Mountain Lookout weather station is located within one of the two broad vegetation types, weather data collected at this station may not be representative of the weather in that vegetation type due to the elevation of the lookout. As a result, it was recommended that the station should be moved to the Black Rock Station, which is manned during the fire season, and which is in a more representative location. This was a minor change, but the process used may reveal more important station location adjustments that could be made in other areas of the forest.

Two more serious problems were identified in forest dispatching procedures.[1] First, the dispatch system operates on a physical scale that is not up-to-date with technological capability. This dispatch system employs three dispatching levels (low, medium, and high) which are determined by the predicted burning indices. The dispatch system does not take unto account the time of day, and, as the dispatch zones are too large, variations in slope, aspect, and fuel type. In specific cases the dispatcher must integrate these variables in the dispatch. The National Fire Danger Rating System, which related burning indices to flame length, has the capability of recognizing large differences in fire behavior in fuel types that are mixed together in one dispatch zone. The present dispatch system deals with these variations in time of day and fuel only by allowing the District Fire Management Officer to change the dispatch level to match his subjective estimates concerning these factors.

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[1] Appendix F

Another problem with the present system is that the dispatch was decided from subjective assessments of what will be needed to have a fire contained at 10 acres (a partially outmoded policy), rather than on an economically based rating of what forces are required to match predicted rate of spread of fire.

The proposed dispatching system addresses these problems, and, further, helps to determine whether a fire, planned or unplanned, might be in prescription. If a fire is in prescription, it could be allowed to burn under observation with a savings in suppression and fuel reduction dollars. In the past, prescriptions have been on a unit basis, each unit having a different range of burn indices (the criteria most often used) that bracket the prescription range. This detail is not always necessary, unless fire management objectives vary sidely between fire management areas. In addition, these type plans have done little to use available technology to make detailed information available about what the on-the-ground conditions (burn indices) are in each management unit.

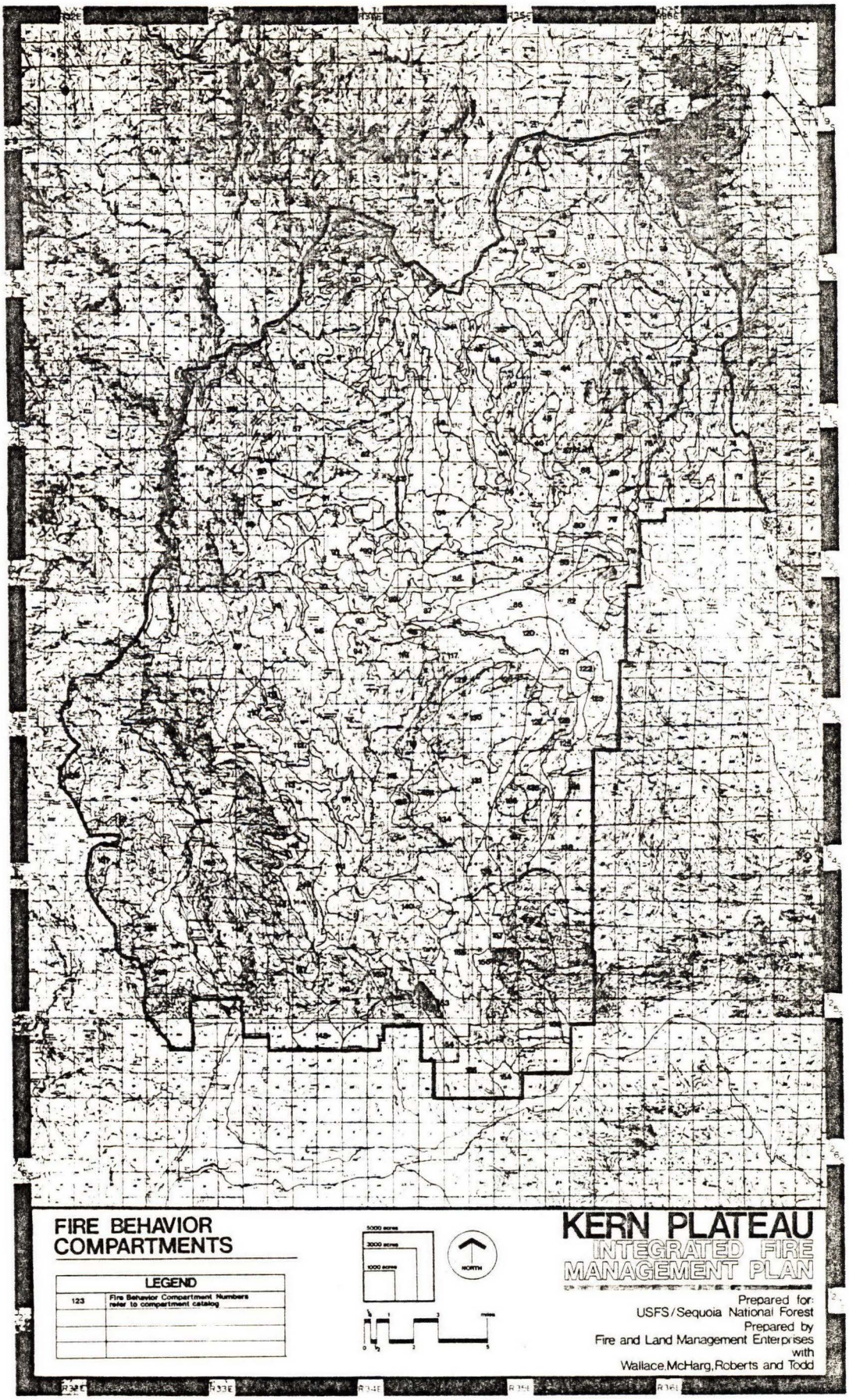
In developing the proposed dispatch system, the planning area was broken into fire management areas (Figure 3), which divide the planning area into discrete areas which are relatively homogeneous with respect to resource values. These fire management areas served as the basic planning unit, and resource values and optimum suppression strategies were identified for each. Fire management areas were further broken into fire behavior compartments for dispatching purposes (Figure 4). Each compartment was a homogenous fuel type and slope class, and fires were assumed to behave uniformly over the compartment. Next, one or more compartments were combined into dispatch zones, the compartments being too small to use individually for dispatching. Each dispatch zone was delineated by some type of fire control line extending completely around the zone (roads, trails, streams, firebreaks, fuelbreaks, etc.). The compartment with the highest fire potential (worst fuel and slope condition) in the dispatch zone was used to predict the burning index for that dispatch zone. In the early afternoon of each day, the dispatcher feeds fire weather observations into AFFIRMS and gets back the predicted burning indices. The burning index will vary on the dispatch zones, depending on the weather station used for that zone, the fuel in the worst fire behavior compartment in that zone, and the slope of the land that fuel is on. The minimum size of a zone was six hundred acres, because dispatchers occasionally have difficulty locating a fire closer than one-half mile at the time of the initial report. In this way, fire behavior, given any combination of fire weather conditions, could be accurately indentified for each fire behavior compartment, and this information could be generalized to each dispatch zone.

Burning indices were grouped into three adjective classes (Table 2) for

Figure 3

Basin
Brush
Horse
True
Dome
FIRE MANAGEMENT AREAS (14)
LEGEND
Fire Management Areas
NORTH
KERN PLATEAU
INTEGRATED FIRE MANAGEMENT PLAN
Prepared for:
USFS/Sequoia National Forest
Prepared by
Fire and Land Management Enterprises
with
Wallace,McHarg,Roberts and Todd

Figure 4


FIRE BEHAVIOR COMPARTMENTS
LEGEND
123
Fire Behavior Compartment Numbers refer to compartment catalog
5000 acres
3000 acres
1000 acres
NORTH
miles
KERN PLATEAU
INTEGRATED FIRE MANAGEMENT PLAN
Prepared for:
USFS/Sequoia National Forest
Prepared by
Fire and Land Management Enterprises
with
Wallace,McHarg,Roberts and Todd

dispatching purposes. Details on how these adjectives are obtained are discussed later. At ahy one time, many dispatch zones would be in each of the three classes, depending on their specific fuel and weather conditions. When a fire is reported in a particular zone, the dispatcher would consult a dispatch book to see which fuel, slope and weather station, and hence which burning index, should apply to that zone. That burning index will determine the dispatch for that zone.

This system takes a different approach from other systems. All the fire management areas have the same ranges for prescribed fires ("low" in Table 2) and for wildfires ("medium" and "high" in Table 2)[1]. The medium and high dispatch levels further break wildfires into two levels of severity. Table 3 indicates tha preplanned dispatch for each fire management area.

In addition, the proposed system provides detailed predictions of burn indices for each dispatch zone, based on recently developed predictive technology (Deeming et. al. 1977 and Albini 1976). Dispatch zones in the proposed system are much smaller than those in the conventional systems to provide the accuracy in fuel and slope information needed for cost-effective dispatching.

The appropriate initial attack alternative for each dispatch zone was determined through a detailed analysis of fuels, topography, and cost-effectiveness. Land use planning determined which areas were in natural fire management regimes. Which fire management areas receive modified attacks and which receive aggressive attacks were determined by the resource values. A zone that shows little fire potential (and thus little potential for costly damages and suppression) would be allotted modified initial attack.

If a fire occurs in an area on a particular day and the dispatch adjective is low, a minimal dispatch would be sent to check the fire. What a minimal dispatch is exactly depends on the resources and accessibility in the particular fire management area. If the small crew found that the fire was burning slowly, if fuels around the area show no threat of conflagration, if the fire is performing a management goal, such as wildlife habitat improvement, fuel-hazard reduction, thinning of dog-hair thickets of regeneration and type conversion, and if weather forecasts are favorable, the fire would be allowed to burn or would receive minimal suppression effort. A fire in a zone that had an adjective rating of "medium" on the same day would have an engine or helicopter dispatched, but no air tankers. The first man on the scene would report to the dispatcher on the actual potential and fire behavior, and the dispatch would be revised accordingly. A fire in a zone that had a high dispatch on that day would receive all available initial attack engines, crews and air tankers. The specific dispatch

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[1]The capability still exists, however, to provide a set of prescription ranges for each fire management area.

TABLE 2

ADJECTIVES FOR VARIOUS BURNING INDEX CLASSES

Adjective	Suppression Methods[1]	Dispatch[2]
Low	Most prescribed burns in this range. Easy to control.	Dispatch is minimal (no bombers). Fire boss reports to dispatcher on arrival and dispatcher adjusts dispatch, as needed.
Medium	Direct attack possible	One or more engines and one helicopter dispatched (bombers on alert). Fire boss reports to dispatcher, who adjusts dispatch as needed.
High[3]	Difficult to attack the fire with direct methods.	Available engines and crews and bombers dispatched. Fire boss reports on arrival, and dispatch is adjusted as needed.

instructions are in Appendix F, and vary with the fire management area.

Although time did not permit the use of FOCUS in this operation, FOCUS could be used to identify the optimal allocation and distribution of initial attack forces. This would be done by selecting several alternative initial attack systems and by running these for a comparison of cost-effectiveness (Appendix A).

Hence, it was recommended that initial attack should be keyed to weather, fuels, and resource values of specific dispatch zones. The fire behavior compartment concept should be implemented for more accurate awareness of burning fuel characteristics and probable fire behavior. Dispatch goals should be set by fire management area. These goals will have a general influence on the amounts and the nature of forces sent to a fire. The fire behavior compartment and fire weather indices will have a more specific influence on the dispatch.

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[1] Details are in Appendix F, Table 2.
[2] Detailed dispatch sheets are in Appendix F.
[3] Includes the high, very high, and extreme levels used by Region 5.

TABLE 3

DISPATCH PRESCRIPTIONS FOR EACH FIRE MANAGEMENT AREA[1]

Fire Management	Dispatch Adjective		
	Low	Medium	High
Baker	M[2]	F	F[3]
Basin	M	M	F
Beach	M	M	F
Brush	M	M	F
Clover	M	M	F
Curlis	M	M	F
Cyrus	M	M	F
Domelands 1	M	M	M
Domelands 2	M	M	M
Golden Trout	M	M	M
Horse	M	M	F
Lookout	M	F	F
Rim	M	F	F
Smith	M	M	F
True	M	M	F

Suppression of Escaped Fires

Next, the most cost-effective suppression strategies for escaped fires in each fire management area were identified. This effort was the second emphasis of this study. Since FOCUS cannot model escaped fire sizes, damages, and costs, it was not helpful in selecting these strategies. To deal with this problem, suppression of each escaped fire identified by FOCUS would be modelled by hand, and several alternative suppression strategies would be compared. The modelling yielded predicted sizes, suppression costs, costs averted, damages, damages averted, and benefits of each strategy for each escaped fire under 50th and 90th percentile fire weather conditions.

The two fire suppression strategies that were considered for cost-effectiveness were, a) aggressive, direct attack, and b) indirect attack. In some cases, a combination of the two strategies was tried as a third alternative.

Modelling fires combined a variety of skills and areas of expertise[4]. The work began in the field with mapping fuel types, resistance to control, and weather zones. The field work is the same type that

[1] Detailed dispatch procedures are displayed in Tables 6-23 of Appendix F.
[2] M = Modified initial attack.
[3] F = Full capability initial attack.
[4] Appendix B has details on these models.

would normally be done by a fuels management technician. In the office, a weather/fuel/slope map was made, separating fuel types by slope classes. Each unit was designated with a code indicating the weather station representing the unit, the fuel type, and the slope class. Fire management areas were defined and mapped according to size, topography and resource values. These boundaries were transferred to a mylar overlay of the same scale as the other maps. 50th and 90th percentile fire weather conditions were determined using several years of fire season observations, processed by FIRDAT.

Albini nomographs (Albini 1976) were used to determine the spread rates of headfires, and the R-5 computer wheel was used to determine the spread rates of backing fires. Spread rates of fires backing downhill were determined by changing settings on the R-5 computer wheel, but spread rates for fires backing against the wind were first converted to effective negative slopes using charts developed by Albini. A table was made (Table 4 of Appendix B) that displayed the number of men available each new hour after detection. A second table (Table 6 of Appendix B) was developed, based on fireline handbook production rate charts, that showed the production rate of these men in each category of resistance to control.

The preferred method of preplanning fires is to model escapes identified by FOCUS. In most national forests, including Sequoia, FOCUS was not yet ready to run at the time of the pilot test. For this reason, it will be necessary to run FOCUS last in the sequence, rather than first. This made it necessary to manually select points of origin of escaped fires, rather than using FOCUS. Once FOCUS runs are available, the FOCUS escapes will be represented by the geographically nearest modelled fire. This procedure brings into the analysis an element of discontinuity that is acceptable when one considers that the FOCUS points of origin are equally theoretical, being based on historical occurrances, rather than any probabilistic models.

Points of origin of fires to be modelled were selected based on points that would spread into large fires, and on historical occurrences. Fire spread rates under specific slope, fuel, and wind conditions were obtained from the spread rate tables, and were used to generate fire perimeters through the use of vectors. The first vectors originated from the point of origin, and succeeding vectors originated from the subsequent fire perimeters. The fireline production table rates were used to model fireline construction progress around the burn perimeter as the fire advanced. Where applicable, no time was taken in constructing line along natural or man-made barriers. The Fireline Handbook (USDA 1975) was used to determine line production rates for bulldozers. The fireline was advanced around the fire until the fire was contained or until reinforcements arrived from outside the forest, whichever happened first.

Man hours on the fire and on mop-up were tallied and transferred to a costing table. Any additional rehabilitation costs were included in mop-up costs. The number of acres burned was determined with a dot grid. The probability of success was determined through the addition of four weighted factors. Suppression costs, area of burn and probability of success were transferred to a summary table.

Several alternative suppression strategies were modelled for each fire. Maps of the areas burned in each strategy were included in a questionnaire[1], which was given to resource managers who were asked to estimate damages and benefits in terms of units (board feet, etc.). The damage and benefit estimates from these questionnaires were assigned dollar values using value guides presented in reports of the Resources Planning Act[2]. The values of damages and benefits were transferred to a summary table (Table 13 of Appendix B). A least-cost-plus-loss model was then used to evaluate the costs and benefits of each alternative fire strategy, and the most cost-effective strategy was selected for each fire management area (Table 4).[3]

Allowable Burn Acreages

Two types of allowable burn acreages were determined for the Kern Plateau. First, the number of acres that would be allowed in any single escaped fire were determined by examining the preferred strategy that would be used (Table 5) and the resulting acreage that would probably burn if such a strategy were used. It is strongly recommended that the Fire Situation Analysis process be used on any actual fires, however, and that the results of that analysis be used as the final guide on allowable burn acreage for a single fire.

The second type of allowable burn acreage was the number of acres that would be tolerated over a fifty year period of natural fires, planned fires, and accidental fires. This calculation was made by estimating the natural periodicity of fires in each fire management area. The natural periodicity was used with the assumption that natural fires occur at the optimum periodicity for any given vegetation type. It is well known that plant and animal ecology, as well as fuel dynamics, are closely tied to natural fire frequency. The calculated allowable burn acreages for a fifty year period are displayed in Table 6.

Note the differences in the approaches to obtaining the results of Tables 5 and 6. Allowable burn sizes on any one fire, in Table 5, are derived from economic, benefit-minus-cost, criteria, while the allowable acreages for a fifty year period are obtained from ecological criteria, the estimated natural fire cycle. This use of both economic and ecological information is based on data subject to changes, but

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[1] Appendix C
[2] Appendix D
[3] Appendix E

TABLE 4

SUMMARY OF STRATEGIES RECOMMENDED (From Table 20)

Fire Management Area	Strategy Recommended[1] 50th % Weather	90th % Weather
Basin	A	A
Beach	A	A
Brush	B	B
Clover	A	A
Curlis	A	C
Cyrus	A	A
Domelands 1	B	B
Domelands 2	B	B
Golden Trout	B	C
Horse	A	A
Lookout	B	C
Rim	B	A
Smith	C	C
True	C	C

the approach brings together two important parameters that are not often considered together.

Fuel Management

Fuels may need further management work before modified suppression strategies are used. Two types of fuel management were considered: fuel break construction and fuel reduction.

Fire models from the analysis of different suppression strategies were also used to test the feasibility of proposed fuel break construction. First, proposed fuel breaks were mapped (Figure 20). The escaped fires that were modelled the first time without fuel breaks, were modelled a second time with the proposed fuel breaks present. Revised total costs were added to the costs of the fuel break construction and this total was compared to the original total cost (without fuel breaks). Table 25 shows the value saved with fuel breaks and the subsequent decision on construction policy.

This pre-attack selection of strategy can prove to be very useful to line officers on an actual fire. The unit resource values derived in this study may also be useful in the Fire Situation Analysis.

[1] A = Direct attack.
B = Indirect attack.
C = Combined direct and indirect attack.

TABLE 5

ALLOWABLE BURN SIZES FOR EACH FIRE MANAGEMENT AREA
(FOR ANY SINGLE ESCAPED FIRE)

Fire Management Area	Allowable Burn Size (ac) 50th % Weather	90th % Weather
Baker	6000-12000	<8000
Basin	<3700	<8000
Beach	<1200	<6000
Brush	18000-30000	<30000
Clover	<10	<20
Curlis	<1000	<4000
Cyrus	<4000	<5000
Domelands 1	<16000	15000-20000
Domelands 2	30-400	300-400
Golden Trout	<13000	<4000
Horse	<100	<20
Lookout	3000-18000	<3000
Rim	6000-12000	<8000
Smith	1000-2000	2000-3000
True	<700	300-700

TABLE 6

ALLOWABLE BURN ACREAGES FOR A FIFTY YEAR PERIOD

Fire Management Area	Total Acres	Estimated Fire Cycle	50 Year Allowable Burn Acres	Acres Burned in the Last 50 Years (1930-79)[1]
Baker	30876	30[3]	51460	12770
Basin	24366	30-100[4]	12183-40610	900
Beach	41385	100[5]	20692	12679
Brush	19623	30	32705	2624
Clover	38967	100	19438	214
Curlis	15810	100	7905	1100
Cyrus	15655	30	26350	11346
Domelands	62700	30-100	31350-104500	8080
Golden Trout[2]	8463	30	14105	6570
Horse	14787	100	7393	400
Lookout	22413	30-100	37355	832
Rim	29202	30	48670	25856
Smith	25947	30	12973	12973
True	25296	100	12648	12648

[1] See Figure 13.
[2] A portion of the Golden Trout wilderness is outside the boundaries of Sequoia N.F., and is not considered here.
[3] The area contains brush. This analysis assumes a 30 year cycle.
[4] The area contains a mix of brush and timber. This analysis assumes a 100 year cycle in timber at high elevation.
[5] The area contains timber. This analysis assumes a 100 year cycle.

FLAME

Figure 5

Golden Trout
7
Clover
14
Beech
4
Smith
3
Lookout
1
Basin
8
Quigley
13
Bingay
5
Domeland Wilderness
12
Horse
9
Bear
10
Keller
11
Trout
2
Cyrus
6
FUEL REDUCTION PRIORITIES (SHADED)
LEGEND
Fire Management Areas
NORTH
KERN PLATEAU
INTEGRATED FIRE MANAGEMENT PLAN
Prepared for:
USFS/Sequoia National Forest
Prepared by
Fire and Land Management Enterprises
with
Wallace,McHarg,Roberts and Todd

Further use was made of the data that came out of this analysis by using the sizes and perimeters of the modelled fires to help determine the cost-effectiveness of fuel management projects. Areas needing fuel reduction were selected based on the modelled fire behavior (Figure 5). The general conclusion of this study was that fuel management should be the emphasis of future management on the Plateau. Fuel breaks were proposed based on model fire behavior, and were tested for economic benefits by modelling pre-construction fire damages versus post-construction damages. Areas that show potential for large fires due to fuel conditions were flagged for fuel reduction operations.

Study should begin on the ecology, administration, and logistics of natural fire management on both plateau wilderness areas. Any action in these areas should be tempered by a sensitivity to the wilderness values being protected.

Resource managers should plan to fund and maintain a system of monitoring fire behavior effects and actual fire management costs. Most economic assumptions in the models used in this study need testing and validation. Dispatching, fire suppression strategies, and other aspects of the plan should be periodically reviewed, especially when new resource values are determined.

Figure 6 presents a flow chart of the process to be used in the event of a fire. See the next section for further specific recommendations.

Figure 7 illustrates the steps needed to develop a fire management plan based on this procedure.

RECOMMENDATIONS

The following recommendations are made as a result of this study of an economically-based fire planning process. Specific recommendations for the Kern Plateau pilot study area are included.

General Recommendations

- Fire management policies should become economically-based. The appropriate and best mix of fire management activities should be assessed with simple economic models. Economic models used to determine the amount of protection should consider the values of the resources being protected.

- Potential benefits of fires under certain weather conditions and fuel conditions should be stressed in future analysis.

- There is an urgent need to support economic studies. Improvements

Figure 6

FLOW CHART OF THE PROCESS TO BE USED IN THE EVENT OF A FIRE

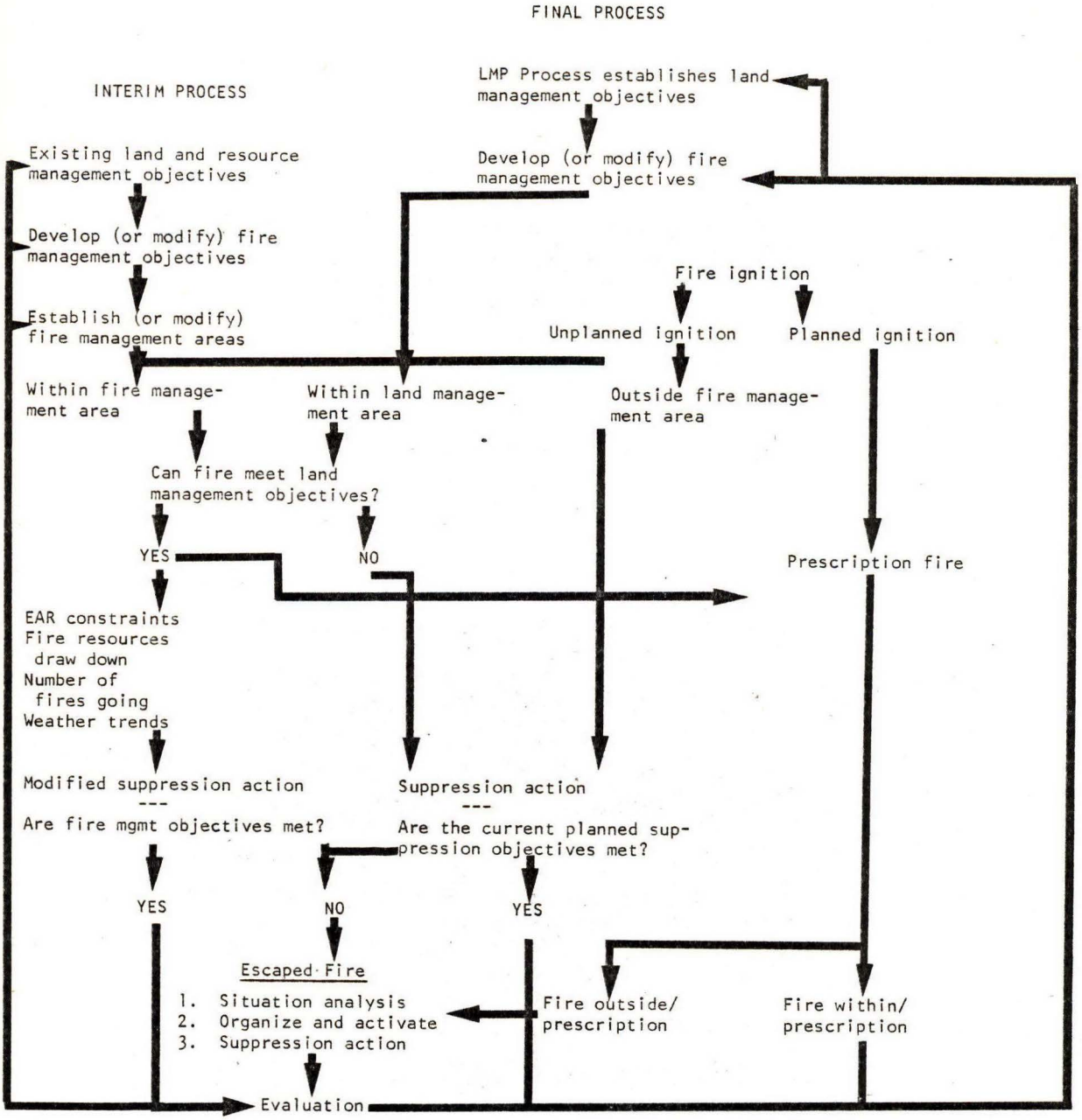
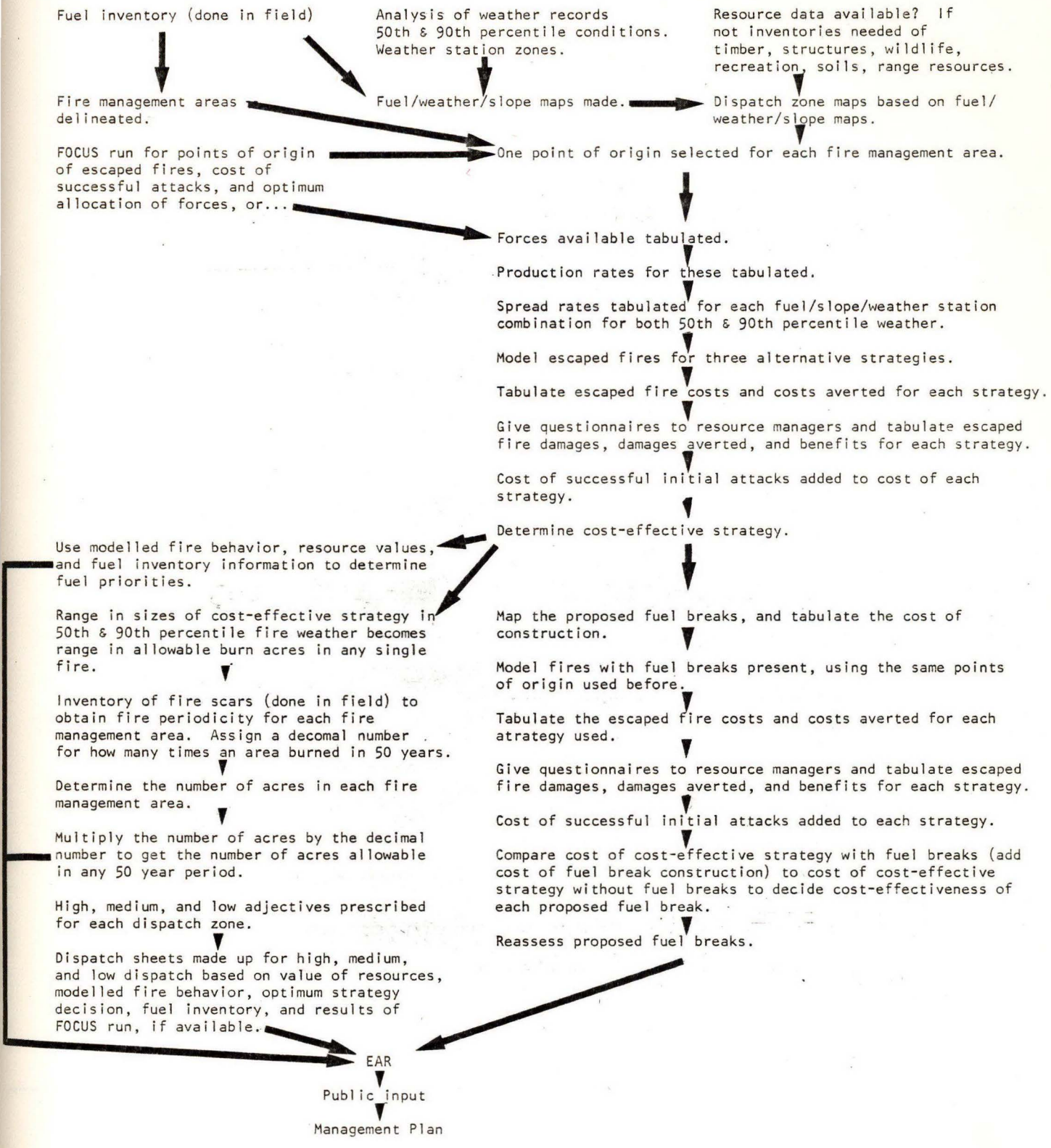


Figure 7

WORK STEPS IN THE PROPOSED PROCESS


Fuel inventory (done in field)
Analysis of weather records 50th & 90th percentile conditions. Weather station zones.
Resource data available? If not inventories needed of timber, structures, wildlife, recreation, soils, range resources.
Fire management areas delineated.
Fuel/weather/slope maps made.
Dispatch zone maps based on fuel/ weather/slope maps.
FOCUS run for points of origin of escaped fires, cost of successful attacks, and optimum allocation of forces, or...
One point of origin selected for each fire management area.
Forces available tabulated.
Production rates for these tabulated.
Spread rates tabulated for each fuel/slope/weather station combination for both 50th & 90th percentile weather.
Model escaped fires for three alternative strategies.
Tabulate escaped fire costs and costs averted for each strategy.
Give questionnaires to resource managers and tabulate escaped fire damages, damages averted, and benefits for each strategy.
Cost of successful initial attacks added to cost of each strategy.
Determine cost-effective strategy.
Use modelled fire behavior, resource values, and fuel inventory information to determine fuel priorities.
Range in sizes of cost-effective strategy in 50th & 90th percentile fire weather becomes range in allowable burn acres in any single fire.
Inventory of fire scars (done in field) to obtain fire periodicity for each fire management area. Assign a decomal number for how many times an area burned in 50 years.
Determine the number of acres in each fire management area.
Multiply the number of acres by the decimal number to get the number of acres allowable in any 50 year period.
High, medium, and low adjectives prescribed for each dispatch zone.
Dispatch sheets made up for high, medium, and low dispatch based on value of resources, modelled fire behavior, optimum strategy decision, fuel inventory, and results of FOCUS run, if available.
Map the proposed fuel breaks, and tabulate the cost of construction.
Model fires with fuel breaks present, using the same points of origin used before.
Tabulate the escaped fire costs and costs averted for each atrategy used.
Give questionnaires to resource managers and tabulate escaped fire damages, damages averted, and benefits for each strategy.
Cost of successful initial attacks added to each strategy.
Compare cost of cost-effective strategy with fuel breaks (add cost of fuel break construction) to cost of cost-effective strategy without fuel breaks to decide cost-effectiveness of each proposed fuel break.
Reassess proposed fuel breaks.
EAR
Public input
Management Plan

needed in the models used in this study, for example, include:
  value systems for intangible resources, such as endanged species, habitat diversity, aesthetics, and human life.
  better value systems for tangible resources.
  the use of the concept of value-at-risk, and other devices employing probability analysis.

- Fire management goals should be redefined. Goals in this study were stated in terms of cost-effectiveness of various policies, rather than on a set burned area goal.

- National Forests should be divided into fire management areas. These areas are selected on economic, administrative and physical criteria. Each area would be given a common set of fire management objectives, fire prescriptions, optimal suppression strategies keyed to fire weather, and special management policies, such as natural fire management policies.

- Goal setting should be done at the level of the fire management area.

- The Fire Situation Analysis process should continue to be used to assess the economic feasibility of suppression alternatives on any escaped wildfire. This process should utilize actual resource values rather than the point system now in use. Effects that cannot be valued, such as the length of the suppression effort and the amount of smoke output, should be considered separately from the resource values, although they may, on occasion, overrule an economically derived decision. The Resource Planning Act resource values (Appendix D) should be used to value resources until better values are available.

- Presuppression spending should be evaluated through the use of FOCUS (Appendix A). Forests that do not currently have FOCUS available should get this system in operation.

- The management of fire should be decentralized and shifted to district offices. Responsibilities in the allocation of the budget amongst fire management activities should be shifted from the Washington Office to the District Fire Management Officer.

- This shift in responsibility should be accompanied by a revised system of project funding. Fuel modification dollars should be increased, and fire suppression dollars should be decreased. The latter should be accomplished through the Fire Situation Analysis process.

- The system of collecting data on costs and damages of wildfires

should be improved, with specific, standardized, follow-ups on any escaped fires. Various alternative suppression plans should be evaluated from the post-fire information.

- The modelling process described could be improved by automating it and using the entire range of fire behavior characteristics, rather than two fire weather levels (Omi 1977), and by using probability analysis (Armstrong 1978). FOCUS may be a useful planning tool for fuel reduction (Appendix A).

- Reducing the use of fossil energy should become a key objective of fire management operations.

Fire Prevention Recommendations

- Fire management areas should be used as a basis for prevention planning.

- Prevention goals should consider the marginal benefits gained with each additional dollar spent (i.e., how many new fires will be prevented by each new dollar spent?). Such a practice will require research studies of prevention productivity or effectiveness on the local level.

- The Plateau recreation plan calls for increasing dispersed recreation. To handle this new emphasis, FPT's should go on horseback, rather than in vehicles, in some fire management areas.

- New symbolic fire prevention signs should be installed at key locations -- the fewer, the better. Special radio transmitters installed at entrances to alert visitors to fire dangers and to provide other useful information should be considered.

- Prevention media should include explanations of the uses of fire, and of new fire management policy.

- The weather indices used for shutdowns appear to be innacurate, and may be causing unneeded shutdowns. Weather observations taken on-site may alleviate this problem.

- In an effort to collect data for prevention planning, visitor counting gauges should be installed at each entrance to the Plateau.

- A new system being developed at the Riverside Fire Lab., called CROSSTABS, may have application on the Plateau in identifying potential prevention problem areas.

- The resource value per acre in Fire Management Areas should be used

to guide prevention priorities (Table 20).

Detection Recommendations

- Fire management areas should be used as a basis for detection planning.

- Detection goals should consider the marginal benefits gained with each additional dollar spent. Such a practice will require studies of the detection productivity on the local level.

- The detection system appears adequate on the Kern Plateau. Seen-area maps should be revised, however, and should be evaluated based on recent and planned logging operations and on new fuel data. Any blind spots with high fuel loads should receive some detection planning.

- BLM is setting-up lightning detection systems in Bishop and Las Vegas, which will be able to look into the Plateau area. These may be of value, and an effort should be made to utilize data from these detectors.

- At some time, a decision process may be needed to balance the use of aerial and lookout surveillance. Kourtz and O'Regan (1968) have developed a useful process to do this. The present system (aerial surveillance only after lighnting storms) is preferred, however, because lookouts use little fossil energy.

- Visibility should be reported with weather, so that this aspect of detection can be monitored.

Dispatching Recommendations

- A method described in this report could be used in other areas to evaluate the location of fire weather stations, the need for new stations, and the redundancy of unneeded stations.

- The innaccuracy of the two reporting weather stations for the Plateau should be corrected by moving the station at Bald Mountain to the Black Rock Guard Station.

- The National Fire Danger Rating system has recently been revised. Some aspects of the new system, notably the new Burn Index, are confusing to users and should be clarified in a publication or memorandum. Particular problems concern the conversion of present dispatch systems, using the old Burn Index, to systems that use the new

index.

- In order to make the dispatch more sensitive to the variations in fuels and slopes found in the dispatch zones, each zone should be broken into a number of smaller zones (Appendix F).

- Dispatch should be generally guided by the management objectives of the fire management area, and specifcally guided by fire weather indices in the particular dispatch zone. Appendix F describes such a process.

- Some further tools are currently being developed at the Riverside Fire Lab that may be of future use. One such tool is FIRECASTING, a fire behavior index model that can be custom-made for specific fuel situations.

Initial Attack Recommendations

- The Kern Plateau's pre-attack plan should be reevaluated, based on the guides contained in this report.

- Initial attack goals should be cost-effective and should consider resource values in the fire management areas. The primary goal should be to keep the total cost of fire management below the value protected. If cost of protection exceeds the value protected, the management is not cost-effective. The least expensive initial attack alternative will be the alternative with the highest benefits-minus-costs, considering both initial attack and suppression benefits and costs (Appendix E).

- Although the policy toward initial attack should change, necessary fire suppression should still be fast, energetic, thorough, and conducted with maximum personal safety.

- Fire management areas should be used as the basis for planning initial attacks.

- Specific attack force numbers and locations should be determined using FOCUS (Appendix A).

- Aircraft should be equipped to operate at night, when the fire is most vulnerable to control.

Fire Suppression Recommendations

- Fire management areas should be used as the basis for fire suppression planning.

- Current suppression objectives should still remain in effect for National Forest System lands not in an approved fire management area. The responsible line officer should organize and activate within the first work period sufficient strength to implement a suppression decision for every escaped fire. This will require an escaped Fire Situation Analysis within the first and each subsequent work shift (USDA, Forest Serbice, Directive, 5130 Fire Suppression, 1/23/78).

- Where fire management areas are established, appropriate suppression actions should be taken to meet the fire management objectives established for the area. Suppression action may range from confinement to control (USDA, Forest Serbice, Interim Directive, 5130 Fire Suppression, 1/23/78). The Fire Situation Analysis should still be used on actual escaped fires to determine the appropriate suppression action. Fire models used in this study will provide much greater accuracy for the Fire Situation Analysis on actual fires.

- Suppression goals for each fire management area should be based on the resource values in that area. Each area should have a preplanned optimal suppression strategy based on fire modelling, as in this pilot study. Preplanned strategies indicated the goals for each fire management area. The fundamental decision made was whether to put the fire out with aggressive direct attack or with a delayed and less expensive indirect attack.

- Optimal suppression strategies should be developed through an economic model that employs suppression costs, damages to resources, enhanced values, damages averted and suppression costs averted. A stylized Fire Situation Analysis should be employed as a first approximation. This analysis should use 90th percentile fire weather conditions combined with the fuels of the most volatile fire danger rating compartment in the dispatch zone. This use of high fire danger weather conditions and volatile fuel situations generates as large and destructive a fire as possible in the modelling. The modelled fire is suppressed with various alternative suppression strategies to evaluate the optimal suppression strategy, in terms of cost-effectiveness. Data derived will provide better input into a Fire Situation Analysis on a real fire, will provide planning goals, will identify areas that need fuel management, and will indicate the required levels of dispatch.

- Suppression strategies should be concerned with minimum disturbance of soil and vegetation, using natural control lines rather than constructing large fire lines when this practice is economically feasible in relation to the values-at-risk.

/////

- An effort should be made by all forests to improve the collection of data on resource damages and suppression costs. Each fire report should have a Situation Analysis attached which uses the economic model employing damages, damages averted, suppression costs, suppression costs averted, and enhanced values (Appendix E).

- The probability-of-escape model used in this report should be improved. Other assumptions of the models used in this study should be examined for possible improvement.

Fuel Management Recommendations

- The fire management area should serve as the basis for fuel management planning.

- Adjacent fire management areas that have greatly differing resource values should be separated by fuel breaks, when feasible.

- Priority in fuel break construction should be given to the primary fuel breaks. Priority in fuel reduction should go to the fire management areas with the highest value per acre and having the most critical slash problems.

- The modelling done could be improved by using the entire range of fire variability rather than two fire weather levels (Omi 1977), and by using probability analysis (Armstrong 1978). FOCUS May be a useful planning tool for fuel reduction (Appendix A).

- National Forest managers should consider expanding firewood and Christmas tree sales to private contractors to reduce fuels and increase forest use.

- Prescribed burning should be used where possible in area fuel reduction. In reducing fuels, soil sterilizers, herbicides, etc. should not be used where fire or hand-labor can be used instead.

Wilderness Fire Management Recommendations

- Natural fire management should be used in the Golden Trout and Domelands Wilderness.

- A specially-trained crew should monitor and, if necessary, contain fires in these areas.

- Fuel breaks, if needed, should be constructed outside the wilderness to prevent fires from leaving the wilderness and from entering the wilderness in broad fronts. Fuel reduction, if needed, should be

done within the wilderness. Fuel reduction needs should be evaluated in terms of the present level of fuels versus natural levels. Present data are not sufficient to advise specifically on fuel management needs in these areas. This data collection should be a priority.

THE CONCEPTUAL FRAMEWORK OF THE PLANNING PROCESS

Summary

The Forest Service is responsible for fire protection on over 200,000,000 acres of wildlands. Depending on the season, this agency hires from ten to twenty thousand employees directly involved in fire management activities, which include fire prevention, fuel modification, fire detection, presuppression, fire suppression, and natural fire management.

The long-term land and resource management goals for National Forest system lands are to provide the full measure of their potential benefits to people on a national, regional, and local scale (FSM 5100 Interim Directive 1/23/78). Fires affect these goals by affecting timber outputs; hazard to life; recreation use; forage production; wildlife and plant habitat; stream flow; visual, air, and water quality; on-site erosion, off-site flood damage to property, transportation, and transmission facilities. Fire management goals should address these effects.

Fire management is by no means a simple task. It is a complex process which requires a balancing of the various components of an Integrated Fire Management System. Such a system should have the following components:

* Prevention of person-caused fires through education, enforcement, and environmental modification.

* Prompt detection of fires which occur through a planned system of fixed observation points (both primary and secondary lookouts), roving ground patrols, and aerial patrols to supplement ground detection during periods of critical fire danger rating or lightning activity.

* Fast initial attack (both day and night) with both ground forces and tactical aerial support based on accurate fire danger ratings and fire weather forecasts.

* Pre-planned and installed fuel modifications systems along stra-

egic ridges, routes of travel, and areas of heavy fuel accumulation.

* Cost-effective suppression guided by resource values.

* Natural fire management and prescribed burning, where appropriate.

Each component of the integrated fire management system is essential to the success of the entire system. If any component is missing or inadequate during periods of critical fire weather, a destructive fire and major damages to life, property, and natural resources may result.

Also inherent in the integrated fire management system is an interdisciplinary approach to setting goals, solving problems, and applying managerial techniques. Wildfires are not solely the concern of fire management officers and foresters. Timber, range, wildlife, and watershed managers are also directly concerned. It follows, then, that forest fire problems should be attacked through the pooled efforts of all concerned disciplines.

Past fire management, however, has heavily emphasized fire suppression. Two factors, the 10:00 a.m. control policy and the 10 acre goal, are the reason for this emphasis. The 10 acre goal, established in 1971, is a presuppression goal that states that presuppression activities should be maintained at a level sufficient to hold fires to ten acres or less. The 10:00 a.m. control policy, initiated in 1935, is a suppression policy indicating that fire suppression should be organized for suppression by ten o'clock the next morning if the fire is not controlled within the first working period.

The success of these objectives has led, paradoxically, to an even more serious fire problem. In many areas, fire suppression has led to dangerous backlogs of dead fuels, which, when ignited, cause critical fire suppression problems and extremely high firefighting costs. Further, these large fires have caused environmental destruction and severe on- and off-site damages. In general, this is a clear result of the failure to recognize fire as a natural force in the forest environment -- a force which we should not attempt to eliminate, but should manage.

The elimination of conflagrations will probably always be one goal of fire management. As long as it is, the 10:00 a.m. policy will have a role in fire management. At any time when there is a high probability of a costly conflagration, then that probability should be minimized, usually through immediate and aggressive action, such as the 10:00 a.m. policy. Often, managers have invoked the policy with the reasoning that, although the potential resource damage was not great, time did not allow for alterantive planning. This problem can only be dealth

with by immediate and aggressive fire management planning.

A precedent has been set by a number of managers who have implemented modified versions of the 10:00 a.m. policy:

* In cases when twenty firefighters are available to attack thirty lightning fires, the fires given delayed attack have had modified suppression.

* Some select, high elevation, post- or pre-season fires have been allowed to burn out in snow banks or rock outcrops.

* Region 3 instigated a "loose herding" practice that has evolved into a sophisticated, tightly controlled delayed attack system.

* In some large Santa Ana conflagrations in Southern California, flanks or portions of a fire front have had no attack pending change in fuel, weather, or topography.

* The Forest Service's Emigrant Basin Wilderness is now being managed in a natural fire program.

* The National Park Service has instigated a "conditional fire" system, in which a suppress/no suppress decision is based on the specific weather, fuel, and topographic conditions.

All of these are cases of modified suppression, which led to considerable savings and eventually to a new policy.

Aside from the problems of piecemeal management, fire management planning efforts have also been hampered by the policy of opening the congressional pocketbook when large fires occur. This practice has led to wasteful management, and eventually to the questioning of the entire management system by Congress.

The past goals of fire management were directed at reducing the number of acres burned in management units. Often, specific acreages were identified as limiting criteria. It is increasingly obvious that these goals need to be reevaluated. A burned area goal ignores many facts. Reducing acreage burned, without considering benefits, may result in benefits averted rather than damages averted (Gorte and Gorte 1977). Prevention of damage does not necessarily involve stopping a fire at a given line: burned acreage is often unrelated to value losses (Zivnuska 1972). Reducing acreage burned should not go beyond the point where the cost of averting loss is greater than the potential loss (Gorte and Gorte 1977). Certain fuel, weather, and topographic combinations create fires that cannot be stopped. In a study of the Los Angeles River watershed system, (USDA 1972), it was found that goals

relating to burned area were unrealistic because they did not account for inevitable large fires. Success in a burned area goal will only lead to even larger areas susceptible to such fires (Kourtz 1972). Finally, fire can be beneficial instead of destructive, as in a prescribed burning.

Goals are far better tied directly to the issue of economics rather than to the intermediary of acreage burned. This release will allow the inclusion of prescribed burning, modified suppression strategies, and natural fire management into integrated fire management planning.

The New Fire Management Policy

In response to a new atmosphere created by the concept of integrated fire management, a revised fire management policy became effective in February, 1978. It states that:

> The basic fire management policy on National Forest System lands is to provide well planned and executed fire protection and fire use programs that are cost-effective and responsive to land and resource management goals and objectives, and supportive of the 1974 Forest and Rangeland Renewable Resources Planning Act resource outputs.[1]

Success in implementing this new policy is most likely to be assured by making available a wide range of professional expertise on special planning units. These pilot projects are essential to demonstrate the value of new approaches in fire management. In turn, this will help create confidence in the widespread application of integrated fire management concepts.

The Sequoia and San Bernardino National Forests, along with two forests from each region, were asked to develop a planning process that would lead to implementation of the new policy. In November, 1978, Fire and Land Management Enterprises (FLAME) contracted with Sequoia National Forest to develop a process for implementing this directive, and to test this process on fire management areas on the Kern Plateau Planning Unit.

The goal of this project was to develop and test a planning process that can be used to evaluate fire management alternatives and establish fire management areas which will benefit and minimize damages of fire, while simultaneously keeping the effort cost-effective. The final product of the process is a determination on the cost-effective initial attack strategy for each dispatch zone, the cost-effective suppression strategy for each fire management area, and the optimum mix of detection, prevention, initial attack, and fuel management

[1] Appendix G gives details on this policy.

dollars for the forest.

In the recommended process, FOCUS is used to identify the optimal allocation and distribution of initial attack forces. This is done by selecting several alternative initial attack systems and running these for a comparison of cost-effectiveness. Since FOCUS cannot model escaped fires, it had an inherent shortcoming. To deal with this problem, suppression of each escape identified by FOCUS is modelled separately, using several alternative suppression strategies. The modelling yield sizes, suppression costs, costs averted, damages, damages averted, and benefits of each strategy in each escape. Using these data, an economic benefits-minus-costs model is used to select the optimal (cost-effective) strategy. The costs of the optimal suppression strategies are summed (i.e., all the escapes in FOCUS alternative A cost X, all escapes in alternative B cost Y, etc.) to give the total suppression cost of each FOCUS alternative. The suppression costs for each alternative are added to the initial attack costs for that alternative, and the totals indicate the most cost-effective alternative.

Further use can be made of the data from this analysis. The sizes and perimeters of the modelled fires can be used to help determine the cost-effectiveness of fuel management projects. Areas needing fuel reduction can be selected based on the modelled fire behavior. Fires modelled in the first analysis can also be used to test the feasibility of proposed fuel break construction. After mapping new fuel breaks, the escapes occured in the optimal FOCUS alternative selected can be modelled a second time. Revised total costs are added to the fuel break construction costs and this total is compared to the original total cost.

Although the preferred way to preplan fires is to model escapes identified by FOCUS, in most national forests, including Sequoia, FOCUS is not yet ready to run. For this reason, it will be necessary to run FOCUS last in the sequence. This made it necessary to select points of origin of escapes, rather than using FOCUS to identify points of origin of escapes (Figure 7). Once FOCUS runs are available, the FOCUS escapes will be represented by the geographically nearest modelled fire. This procedure brings into the analysis an element of discontinuity that is acceptable when one considers that the FOCUS points of origin are equally theoretical, being based on historical occurrances, rather than any probabilistic models.

Tools Available for Selecting Alternatives in the Plan

A number of computer-based and other technological tools are available

for the fire manager. Those used in this study include:

1. FIRDAT. A computer system designed to summarize AFFIRMS weather data. 50th and 90th percentile fire weather were determined through FIRDAT.

2. AFFIRMS. A computer system designed to accept weather data and return fire behavior indices. Weather data from fire weather stations are routinely put into the AFFIRMS system via teletype. AFFIRMS has an integral fuel classification system that was not used in this study, as all fuel data were organized using Albini's classification system (Albini 1976).

3. DFNIV. A computer system calculates fuel loading, given fuel data tally sheets.

4. Albini's fuel classification system. This system provides spread rates and other fire behavior characteristics of various fuel types.

Selecting Criteria to be Used in Evaluating the Plan

Criteria used in the evaluation of alternative management plans are as follows:

1. Cost effective (highest benefit-minus-costs).

2. Financially feasible (affordable).

3. Technically feasible.

4. Legally feasible.

5. Politically feasible.

6. Acceptable consequences.

7. Administratively feasible.

8. Least reduction or greatest increase of outputs.

9. Least degredation or greatest enhancement of the environment.

Locating Weather Zones and Weather Stations

Dispatch systems presently in use often have problems due to weather data that poorly represent the dispatch zones. The first effort of

revising fire management planning should focus on this problem.

Fosberg and Furman (1973), in an effort to identify a process that could be used to select fire weather zones, used a complex system employing the equilibrium moisture content adjusted for the fuel moisture of living material. They concluded, however, that both elevation and broad vegetation types correspond well with the climate types that resulted. Fosberg (1978) feels that broad vegetation types can be used to get a good first approximation of the fire climate types in an area.

In the recommended process, a broad vegetation map is employed to determine the weather zones in a planning area and to compare these zones with weather station locations. This analysis may reveal unneeded stations and misplaced stations.

Selecting Fire Management Areas

The Kern Plateau is divided into fire management areas (Figure 3), which are discrete areas of relatively homogeneous resource values. Each value area has its own dispatch plan and suppression strategy; the entire Plateau is analyzed to determine the best mix of alternative fire management activities.

The proper selection of fire management areas is essential to their usefullness in the analysis for appropriate fire suppression strategies. Each area must be defined in such a way that a selected fire strategy would apply to most fires in that area. This pre-attack planning is the primary purpose for selecting fire management areas.

The following criteria were set for a fire management area delineation:

*There must be enough areas to resolve differences in resource values, management objectives, and initial attack and suppression strategies.

*Areas must be logical assessment and planning units. The area must have reasonably homogeneous resource values. If for example, one part of an area has high timber values, and the other part has no timber value, the area would be divided into two areas, unless other considerations dominated.

*The fire management area must constitute a relatively tight fire compartment. In the same manner that ships contain compartments separated by bulkheads, fire management areas should be fairly isolated by fuelbreaks, ridges, or natural breaks in

the fuels.

*Fire management areas correspond in some cases to preattack units (USDA, FS Preattack Handbook, 1970). They also often conform with the landscape architect's concept of "character type", and area of land with common distinguishing visual characteristics (USDA 1977).

*The selection of the unit should also be based on fire history, intensity of planning, special problem areas, field utility.

These criteria often lead to watersheds or basins being designated as fire management areas.

Mapping Fire Danger Rating Compartments--Bringing Hazards, Risks, and Weather into the Picture

Each fire management area was divided into fire dange rating compartments for dispatching purposes (Figure 4). Each compartment contains a homogeneous fuel type and slope class, so fires are assumed to behave uniformly over the compartment. The minimum size of a compartment is six hundred acres, because dispatchers occasionally have difficulty locating a fire within one half mile on the initial report.

Fire behavior was calculated for each fire danger rating compartment; and dispatching levels, resource values, and optimum suppression strategies were calculated for the larger fire management areas.

Two problems were identified in forest dispatching procedures[1]. The system presently is use employs two dispatching levels determined by the predicted burning indices (1972 NFDR system). This preplanned area dispatch system does not account for time of day, slope, aspect, or fuel type. The new (1978) National Fire Danger Rating System, which ties burning indices to flame length, shows that various fuel types will behave quite differently in the same fire weather conditions. For example, Countryman (1955) noted that temperature may be twice as high in clearcut areas as in closed forests. Winds may increase as much as five times in clearcut areas. The resultant differences in moisture can cause fires to start easier, spread faster, and burn hotter. Spread rates on clearcuts can be up to 4.5 times as fast, and control efforst can be twenty times as difficult, as in adjacent closed-canopied forest. The current dispatch system provides for variations in time, fuel, and topography only by allowing the District Fire Management Officer to change the dispatch level to match his subjective estimates concerning these factors. Another problem

[1] Appendix F

with the present system is that the dispatch was decided from subjective assessments of what may be needed, rather than on an economically-based rating of what forces are required to match the predicted rate of spread of a fire.

Prevention Planning--Becoming More Efficient

At this time, no analysis is available to evaluate cost-effectiveness for fire prevention. The question readily lends itself to marginal analysis, in which each additional dollar spent on fire prevention would be compared to the amount of marginal benefits derived in terms of reduced ignitions and subsequent reduced initial attack and suppression costs. The main deterrent to this analysis is the lack of data on a relationship between prevention efforts and number of fires prevented. The two main problems in collecting such production function data are, 1) the geographically specific nature of the relationship, and 2) the changing baseline variable of the number of visitors.

In view of these problems, the question of prevention dollars to be invested was deferred pending further research.

The process proposed is useful, however, in planning prevention priorities (Table 21). These priorities should be based on the value per acre of the resources in Fire Management Areas. The value per acre is one informational output of the planning process (Appendix B). Fuel inventory information can be used to determine whether a fire management area needs a priority rating.

Detection Planning--A Problem of Functions

Kourtz and O'Regan (1968) have published a technique in which the optimal combination of aerial and lookout detection systems can be determined, given a fixed budget. This model can be of use in allocating dollars between these two activities, but is not necessary in planning for small areas.

The problem with production functions discussed for fire prevention also applies to detection, and no means of determining a cost-effective level of detection funding is yet available.

Initial Attack Planning--The Best Use and Deployment of Forces

Initial attack planning must be done for specified fire weather conditions: an initial attack plan for average, or moderate, weather con-

ditions would fail under severe fire weather, and a plan designed for extreme conditions would be too costly to be feasible under normal weather conditions. The standard solution to this dilemma is to have forces available, or on reserve, to handle most conditions and to cancel leaves and increase manning levels on extreme fire danger days. Faith in reserves has led to catastrophic situations in cases where forests called for reserves from other forests at just the time that these were committed at home. Such conditions are purported to occur approximately once each decade, the last such occurrance being in 1970 in Southern California.

In the recommended planning process, FOCUS is used to determined the optimal allocations and distributions of initial attack forces. Four alternative allocations are recommended for testing with FOCUS: 1) attack forces as they were in 1978, 2) attack forces as they were in the 1972 plan, 3) the better of 1 or 2 above, but without air attack, and 4) the best of 1, 2 or 3 above, with any small, specific changes that local managers desire to test. FOCUS outputs will give initial attack costs, with damages and enhanced values calculated from the acreage burned. Most of these alternatives will have firea that escaped initial attack.

The suppression costs and damages of the initial attacks (from FOCUS) and of the suppression efforts (from fire modelling) will be summed, and the enhanced values subtracted to generate the total costs of each alternative (Figure 2). The alternatives will then be ranked in order of costs. Damages averted and suppression cost averted for each alternative will then be determined by subtracting costs from the next most expensive alternative. The best alternative will then be the one with the highest value of (enhanced values+damages averted+ suppression cost averted) - (suppression costs+damages).[1]

Initial attack strategy can also be approached through economic models. Past policies have assumed that costs and damages increase exponentially as area burned increases (Policy Analysis Staff 1977). This assumption leads to the conclusion that escaped fires should be attacked aggressively to minimize costs. The Staff report, however, offers a more realistic view, which is supported by statistical analysis of trends in fire size and increased costs of suppression (Figure 8). The cost curve in Figure 8 illustrates that excessive aggression in initial attack results in high costs and low damages. An example of this would be when air tankers are used on a fire of low intensity, where a less aggressive attack may result in more acres burned, but lower costs. The proper balance of attack costs and damages to resources will depend on the value of the resource. Initial attacks should therefore be designed to yield a cost-plus-loss minimum.

If FOCUS is not available to be used to test manning levels and loca-

[1] Appendix E

TABLE 7

PLAN NUMBERS

B1 - RANGE NUMBERS

Plan Number	Fuel Model A	B	C	D	G
1	0-1	0-18	0-2	0-7	0-8
2	2-3	19-30	3-8	8-14	9-16
3	4-8	31-37	9-14	15-19	17-25
4	9+	38-44	15-18	20-23	26-31
5		45+	19+	24+	32+

1. Find B1 for Fuel Model
2. Determine Plan Number
3. Go to Table 3

TABLE 8

FIRE DANGER RATING

IGNITION COMPONENT 1:00 p.m. PST	Plan Number Based on B1 1	2	3	4	5
0-45	L	L	M	H	H
46-65	L	M	H	H	H
66-80	M	M	H	H	H
81+	M	H	H	H	H

Using Plan Number from Table 2 and Ignition Component, to determine FIRE DANGER RATING

L = Low M = Moderate H = High

FLAME

tions, it is suggested that a process be used that integrates fuel, weather, and resource value data. Fuel and weather data are first integrated to yield a fire danger rating. The process for generating the rating which is displayed in Tables 7 and 8 is based on a system that is currently being revised, but serves as a guide. The fire danger rating is next weighted against the resource value per acre (see Appendices C and D for methods used to get these values) to determine the initial dispatch (Tables 6 to 23 in Appendix E). The dispatch is planned separately for each dispatch zone. The delineation of these zones is explained in Appendix E. An example of the results of such an effort is given in the section entitled Recommendations for a Fire Management Plan for the Kern Plateau.

Suppression Planning--Getting the Most From Each Dollar

1. The Approach

Optimum suppression size would be best solved by determining the value of the second minimum in the curve in Figure 8. This dip is caused by the existence of an ideal size at which a fire can be contained, usually in relation to a line of control that is less expensive to construct, such as a ridgeline or established fuelbreak. It should not be inferred that the optimum suppression size is a fixed value (Mills 1978). This optimum size will vary from management unit to management unit, as resource values, suppression opportunities, and fire behavior vary.

Ideally, the technique chosen to find the optimum strategy would utilize a large file of data on fire occurrence, behavior, damages and costs. These data are not currently available for any management units in the national forest system, primarily due to the problem of assigning costs to damages. As a substitute for such data, the concept of the stylized situation (Mills 1978) was used in this study. In this approach, a large fire was simulated in each fire management area. Several alternative strategies that could be used in the suppression of that fire were modelled, and the optimum strategy was selected based on economic models (Appendix E).

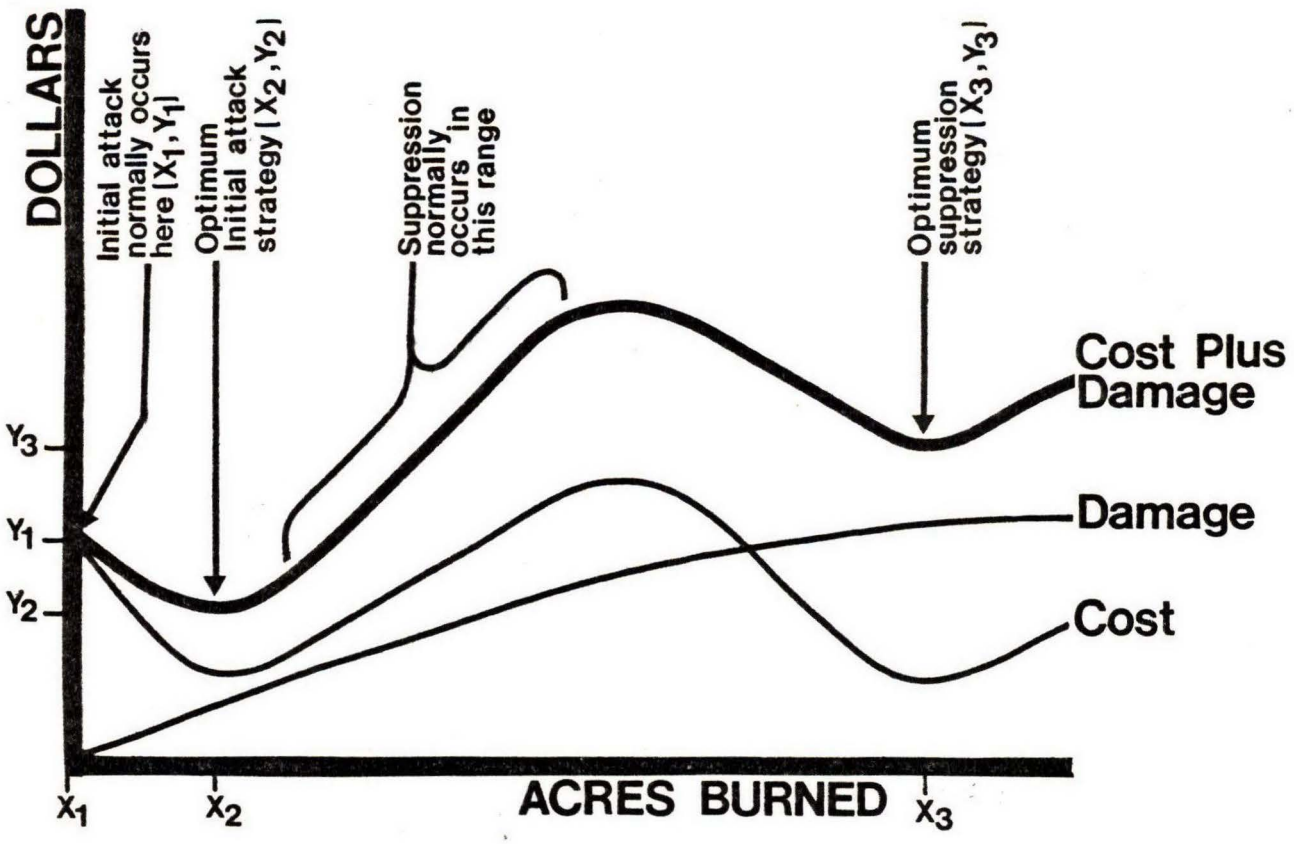
2. Modelling Fires and Considering the Alternatives

Modelling fires combined a variety of skills and areas of expertise[1]. The work began in the field with mapping fuel types, resistance to control, and weather zones. Although the field work took time, it included no work that would not normally be done by a fuels management technician. In the office, a weather fuel/slope map was made, separating fuel types by slope classes. Each

[1] See Appendix B for details of these methods.

Figure 8

COST CURVES IN FIRE SUPPRESSION
(Policy Analysis Staff 1977)



unit was designated with a code indicating the weather station representing that unit fuel type, and slope class. Fire management areas were defined and mapped according to size, topography and resource values. These boundaries were transferred to a mylar overlay of the same scale as the other maps. 50th and 90th percentile fire weather conditions were determined using several years of fire season observations, processed by FIRDAT.

Albini nomographs (Albini 1976) were used to determine the spread rates of headfires, and the R-5 computer wheel was used to determine the spread rates of backing fires. Spread rates of fires backing downhill were determined by changing settings on the R-5 computer wheel, but spread rates for fires backing against the wind were first converted to effective negative slopes using charts developed by Albini. A table was made (Table 4 in Appendix B) that displayed the number of men available each new hour after detection. A second table (Table 6 in Appendix B) was developed, based on fireline handbook production rate charts, that showed the production rate of these men in each category of resistance to control.

Points of origin of fires to be modelled were selected based on points that would spread into large fires, and on historical occurrences. Fire spread rates under specific slope, fuel, and wind conditions were obtained from the spread rate tables, and were used to generate fire perimeters through the use of vectors. The first vectors originated from the point of origin, and succeeding vectors originated from the subsequent fire perimeters. The fireline production table rates were used to model fireline construction progress around the burn perimeter as the fire advanced. Where applicable, no time was taken in constructing line along natural or man-made barriers. The Fireline Handbook (USDA 1975) was used to determine line production rates for bulldozers. The fireline was advanced around the fire until the fire was contained or until reinforcements arrived from outside the forest, whichever happened first.

Man hours on the fire and on mop-up were tallied and transferred to a costing table (Table 11 in Appendix B). Rehabilitation costs were included in mop-up costs. The number of acres burned was determined with a dot grid. The probability of success was determined through the addition of four weighted factors. Suppression costs, area of burn, and probability of success were transferred to a summary table (Table 13 in Appendix B).

Maps of the areas burned in each strategy were included in a Questionnaire[1] which was given to resource managers, who were

[1] Appendix C

asked to estimate damages and benefits in terms of units (board feet, etc.). The damage and benefit estimates from these Questionnaires were given dollar values using value guides presented in reports on the Resources Planning Act[1]. The values of damages and benefits were transferred to a summary table. A least-cost-plus-loss model was then used to evaluate the costs and benefits of each alternative fire strategy, and the most cost-effective strategy was selected for each fire management area (Table 4).[2]

The method outlined above could be varied for different problems. As mentioned earlier, the process would have greater internal consistency if FOCUS was used to located the points of origin of escapes. Bolander et. al. (1972) described an alternative randomized method for locating the point of origin. The method used depends on the problem being addressed. The same option exists for choosing the fire weather conditions for modelling. Two levels of fire weather, 50th and 90th percentile, were used to give some flexibility to the results.

3. Determining the Resource Values Enhanced and Damaged in the Modelled Fires

Once fires have been modelled, a process is needed to determine what economic costs, damages, and benefits the particular fire intensities and coverages will have on a given piece of land. This section describes the logic used in writing a questionnaire (Appendix C), that was given to resource managers to obtain information on the benefits and damages of each fire modelled.

a. Wildlife

The wildlife resource is a combination of wildlife breeding stock and habitat. Food, fur, recreation, and ecological function are products of the wildlife resource. These physical products can be measured not through hunting days, fishing days, visitor days (which are recreational resource products), but through the number of animals and the quality of the environment. Crosby (1976) believes that it is reasonable to appraise only game animals as indicators because the maintenance of game animals in a habitat is intimately related to food chains and to the quality of the site and its ability to provide food and cover.

Disturbance of a site by fire brings about changes in both animal populations and habitat. Populations may be temporarily reduced by death, particularly of the young and those which have limited mobility. Animal populations will also

[1] Appendix D
[2] Appendix E

be influenced through changes in habitat from burning. Many reports confirm beneficial effects of fire on a number of game animals, including deer.

Size and intensity of the fire will be a prime factor in the amount of fire-caused change. Many of the fires modelled were intense, large brush fires. It should be noted, however, that fires are often patchy; for example, although the Marble Cone Fire burned 179,000 acres, only about 50% of the 179,000 acres actually burned.

The differences in effect of a severe fire and a light fire on wildlife populations is not well documented, primarily because few researchers have acknowledged this difference. Observations indicate however, that the difference exists and should be accounted for. One effect of a lighter burn will normally be a smaller coverage of the burn area, which will leave more unburned area and a greater habitat diversity.

Many species of wildlife are relatively mobile and are able to escape from fire (with the possible exception of young and weaker individuals).

Fish cannot, of course, escape a fire, and fire will change the temperature and nutrient of their habitats. The effects of fires will vary with the topography and vegetation in each management unit. Some stream fisheries may not actually be affected by sediment loads from fires, since they are frequently restocked. These streams should not be included in a damage inventory.

Only fisheries within or bordering the modelled fires were considered affected, as estimates of the extent of downstream damage would be speculative. The Questionnaires yielded estimates of the number of fish per hundred feet of stream affected. Total numbers of fish were calculated from these figures. Estimated values for the fish were obtained from the American Fisheries Society, North-Central Division. Full recovery time estimates ranged from two to four years.

b. Range

Range resources include grasses, herbs, browse plants and soil productivity. The product of these resources is forage, which can be measured in tons/acre or anumal unit months (AUM's). Forage is an annual crop that may be partially

burned, but rarely entirely destroyed. A range fire may cause damage to the year's forage, and possibly the next year's. Some grasses may benefit from fire, and prescribed burning is often used in range management. The Questionnaire asked managers to estimate damages due to modelled fires from the cost and loss of revenue of having to move animals in the event of a fire-caused reduction in forage or the cost of supplemental feeding, the cost of range recovery and damage to improvements, and the cost due to animal mortality.

c. Recreation

Recreation resources include natural features, such as meadows, forests, and other vegetation, soil, rocks, water, and weather, historical events, wildlife, topography, geological formations, scenery, and man-made features. The product of recreational resources is human satisfaction from experiencing recreational activities. This satisfaction can be measured in user-days, hunting-days, or fishing-days. In considering the impact of fire, increases and decreases in hunting and fishing days due to changes in the recreational resources were estimated.

In estimating the effects of modelled fires, managers were asked to estimate which improvements may be damaged or lost and the cost of repair or replacement for each fire. In contrast to these improvements, recreationists themselves are highly mobile. If fire destroys one part of a recreation area, they will likely find another nearby area of an alternative activity, rather than cancelling or cutting short their visit. Exceptions may occur when recreationists are going to an area to visit a specific object, such as the world's largest tree, a specific site, such as the only available campground, or an area where recreation resources are very limited. Displacement will occur only until the damaged resource recovers. Repairing the facilities that existed before the burn will, in some cases, alleviate any predicted decreases in visitor use, but usually only in the case of a light fire. If repairing the facilities will not alleviate the problem, then a unique natural feature may have been changed. No fires modelled had such an effect.

In some cases, fires will cause recreational benefits, such as improved habitat, increased points of interest, better visibility, variety of vegetation, enhanced bird watching, new crops of berries, or improved access. This will normally occur if the burn is light. In special cases, burning may

necessitate closure of the area to the public. An example might be closing a trailhead due to damage to a footbridge after an intense burn. No closures were needed on any modelled fires. No collection fees or hunting and fishing license fees were lost due to these burns.

In other cases, there may be archeological or historical attractions that can be damaged or destroyed by fire. Archeological digs and stone walls are not normally damaged by fire and would not be considered. No fire-damageable archeological features were found on any modelled fires.

d. Timber

Timber resource values were considered on commercial forest land only. Timber was valued in four size classes. Merchantable stems were divided into 1. 12 to 24 inch dbh, and 2. greater than 24 inch dbh classes. Immature timber was divided into 1 to 4.9 inch dbh and 5 to 11.9 inch dbh classes (average ages of the immature classes are 25 and 67 years, with ranges from 0 to 40 years and 41 to 70 years respectively).

The timber resource questionnaire asked for standing volumes and acreages for each size class in each fire. Ten percent of the largest size class volume was assumed to be lost in fires of the 90th percentile fire weather class, because it was estimated that ten percent of the larger stems would be killed and would not be salvagable. No volume was assumed lost in the 50th percentile fires (Table 9).

TABLE 9

PERCENT LOSS ESTIMATES FOR LOSS CALCULATIONS ON TIMBER VOLUME

Size Class	% Loss in 50th % Weather	% Loss in 90% Weather
Greater than 24"	0	10
12-24"	10	50
5-11.9"	50	100
1-4.9"	100	100

Fifty percent of the 12 to 24 inch bdh stems were assumed lost in a 90th percentile fire weather fire. These losses were valued at $70/MBF (thousand board feet).

In immature stands, the value of the timber is based on the present value of expected stumpage at maturity (Brown and Boster 1978). The expected stumpage is obtained from the inventoried stumpage in the 12-24 inch classes. In a 50th percentile fire, 50 percent loss was assumed to occur in the 5 to 11.9 inch class, and all would be lost in the 1 to 4.9 inch class. In a 90th percentile fire all would be lost in both classes (Table 9). Time to maturity was calculated as the difference between mean age of the stand and age at harvest, which was assumed to be approximately 100 years. Calculated time to harvest was therefore 75 years for the 1 to 4.9 inch class and 23 years for the 5 to 11.9 inch class.

An example value calculation can be taken from the Basin Fire Management Area (Table 10). The direct attack strategy in 50th percentile fire weather resulted in 3645 acres burned. There was 9,800 MBF of timber in the greater than 24 inch class in standard, special and marginal component lands (unregulated lands are not included in the calculations).

On a 50th percentile fire weather fire, no volume or value would be lost in this size class. There was a total of 2150 MBF in the 12 to 24 inch class. Ten percent of this would be lost, at a value loss of $15,120 ($70 X 2150 X .1). There were 24 acres of stems from 5 to 11.9 inches in special and standard component lands, with an expected yield of 432 MBF. 50 percent of this volume would be lost, at a value of $15,120 to be expected in 23 years. Discounted at 5 percent, this is a present value of $4,922. There are 60 acres in this size class in the marginal component, with an expected yield of 720 MBF in 23 years, with a present value of $16,406. There are 12 acres of 1 to 4.9 inch material on standard and special component lands and 30 acres on marginal component lands. All this volume would be lost. The value lost would be the present value of expected stumpage in 75 years. Expected stumpage on the standard component and special component lands is 18 MBF/ac and on marginal lands is 12 MBF/ac (Table 10). The expected yield in 75 years would be 215 MBF (18 X 12 acres) on special and standard lands and 360 MBF (12 X 30 acres) on marginal lands; a total of 576 MBF worth $40,320 in 75 years (note the incorrect assumption that a harvest value of $70/MBF will still hold in the year 2054). $40,320 discounted for 75 years at 5 percent is a present value of $1,038. The total value lost in all size classes is shown in Table 11.

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TABLE 10

EXPECTED GROWTH BASIS FOR CALCULATIONS

Component	Expected Growth (MBF/Acre)
Standard	18
Special	18
Marginal	12

TABLE 11

CALCULATION OF TIMBER VALUES DAMAGED BY 50th PERCENTILE FIRES

Size Class	MBF	MBF at Risk	Acres	Pot. MBF	% Loss	Pot.$	Present Value
Standard and Special Component							
24" plus	3500	0					-0-
12-24"	1075	108					7,560
5-11.9"			24	432	50	15,120	4,922
1-4.9"			12	216	100	15,120	389
Marginal Component							
24" plus	6300						-0-
12-24"	1075	108					7,560
5-11.9"			60	720	50	50,400	16,406
1-4.9"			30	360	100	25,200	649
			Cost to Replant 42 Acres:				$18,060
					TOTAL:		$55,546

A 90th percentile fire would do more damage on the same area (Table 9). It should be noted that the 90th percent fire which was actually modelled burned a different area, and the figures noted in the 50th percent fire are not comparable.

Ten percent of the greater than 24 inch stems would be lost, for a loss of 1973 MBF, and a value of $138,110. Fifty percent of the 12 to 24 inch stems would be lost, for a loss of 2280 MBF, and a value of $159,600. All the 5 to 11.9 inch stems would be lost. There are 82 acres in this size class in standard and special component lands. The potential yield would be 1476 MBF, at a value of $103,320 in 23 years, or $33,633 present value. There are 133 acres in the marginal component, with a potential yield of 1596 MBF, and a present value of $36,367. There are 24 acres of 1 to 4.9 inch class material in standard component, with a present value of $779. 66 acres in the marginal component has a present value of $1,428. Total value lost would be $369,917, which is substantially more than the loss in the 50th percent fire.

Replanting was simulated on any sites where all trees were killed. This would include all trees in the 1 to 4.9 inch classes in 50th and 90th percentile fires, and all trees in the 5 to 11.9 inch class in the 90th percentile fires. Replanting is estimated at $200/acre for site preparation and $170/acre for planting (includes stock). In addition, thirty percent of the area would need subsequent plantation release at a cost of $200/acre.

e. Water

The Plateau is a prime watershed area. Most of the precipitation occurs in the form of snow, but there are high intensity thunder showers during the summer months, which can cause surface erosion in areas burned by wildfires. The goals of watershed management on the Plateau are to maintain or enhance soil productivity, maintain or improve water quality, and increase water yield.

Watershed stability after burning varies widely, depending on the size of the burn, the vegetation cover, substrate, slope, and amount and intensity of precipitation. If watersheds are relatively stable, then the damage of fire would be low. Watersheds with no planned use or with stable soils are not considered in a damage analysis. In other watersheds, which provide water uses, and which are not stable, a large fire may do measurable damage that should be appraised. In some cases, however, use or value of watersheds may be small enough that no restoration action would be taken in the event of a fire. For instance, although water is contributing to a reservoir, that reservoir is not currently being used at capacity, and increased silting would not necessitate action.

Sometimes, experience has shown, even severe fires cause little damage to on-site and off-site watershed values. Watersheds in which no post-fire action would be taken are also not considered in the damage appraisal.

In the remaining fire management areas, some action would be taken. The Questionnaire asked watershed managers to estimate the watershed damage that would occur after each modelled fire. Stream bank stabilization was estimated at from $8,000/mile, based on experience on the Stanislaus National Forest, to $100/mile, which would cover only an inspection and minimal work. Access into an area to be rehabilitated was taken into account by either reducing the amount of rehabilitation, and thus cost per mile, or by elevating the cost, if the rehabilitation was essential.

f. Improvements

Real estate and developed values include buildings of all kinds, bridges, roads, powerlines, and fences. Recreational improvements such as campgrounds and toilets are considered in the Recreational Questionnaire. Actual value of the land was not considered, as the value will return to normal in the long-run. Resource managers were asked to identify only improvements that may be damaged or destroyed, and to estimate the cost of repair or replacement, whichever was appropriate. Fires in populated areas may cause economic impacts such as traffic hazards and delays, air and automobile accidents, increased demand for electrical power for lights, water pumping, and other energy uses. Evacuation, vandalism and theft requiring special police forces were also considered. In populated areas, the environment may need restoration.

4. Getting Answers Through Questionnaires

Timber, Range, Recreation, Real Estate, Watershed, and Wildlife Questionnaires[1] were designed to help resource managers inventory the damages and benefits of each fire in the fire map package derived from the modelling. Managers in the Forest supervisor's office were asked to identify specific impacts of fires on resources. The Questionnaires were designed to reduce the amount of effort and speculation involved in the inventory. The difference between total resource values and actual values damaged was emphasized in an attempt to reduce bias as much as possible.

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[1] Appendix C

5. Improving the Models

For the most part, probabilities were not included in this analysis. Each fire that was modelled was assumed to have a 100% probability of occurring. Because of this deficiency, the concept of value-at-risk did not come into the analysis. Value-at-risk has two components: the first is a probability distribution that deals with the biological and physical effects of fire, and the second is an assessment of the economic impact of these effects (Gorte and Gorte 1977). Instead, each fire strategy was given damage and benefit values that were assumed to be absolute. Probability did enter into considerations of the success of each strategy[1].

The tallies of values lost concentrated on the real values that would be lost, rather than all the values in the area. For example, timber that was not planned to be logged or that could be salvaged, buildings that were abandoned, phone lines no longer in use, and range not being used were not considered values lost. Some resources, such as endangered species, and diversity of ecosystems, have important social values, but no defined dollar values. These are considered only as they relate to measurable variables, such as visitor days and deer AUM's. A project is currently underway to obtain realistic economic values for resources (Mills 1978). This project used values from the Resources Planning Act[2], but any values can be substituted at any time.

Determining the Allowable Burn Acreage

One of the goals of this study was to develop a process for determining the number of acres that could be allowed to burn in each fire management area. The term "allowable burn" can be interpreted in two ways. First, the term can apply to how many acres burned will be tolerated in any one escaped fire. This figure depends on the value of the resources being burned, the benefits of the burning, and the costs, costs averted, and damages averted by chosing a particular fire suppression strategy over another alternative strategy. It is an economic question. Second, the term can apply to how much area burned can be tolerated in any given period of time by any number of escaped fires. Although this aspect of the term has economic implications and an economic approach can be taken, the problem of determining an allowable burn over a period of time is ultimately a biological matter.

Allowable burn sizes for any single escaped fire were based on the economic analysis used to determine suppression strategies in the previous section. The probable size of the preferred strategy is

[1] Appendix B
[2] Appendix D

the allowable burn. This figure is useful as an administrative guide. In the event of an escaped fire, however, it is strongly recommended that the Fire Situation Analysis technique be used to make the specific decision on that fire.

The second application of the term is more elusive, as biological criteria become important. Today, it is clearly understood by fire managers that vegetation will burn, regardless of our efforts to prevent this from occurring. Suppression and attack efforts have, in many cases, prolonged the period between burns, but the success of this effort often leads to catastrophic results. When the fire ultimately occurs, it is often much worse, due to unnaturally high loads of fuels. This fact of fuel dynamics, which has eluded fire managers for years, is now recognized. The second key to allowable burn acreage now coming to light is that natural fire frequencies are keyed to the biological aspects of fuel dynamics (Rundel and Parsons 1979). The relevant points are: first, in the Sierra Nevada natural fires occur when there is sufficient fuel to carry a fire, and second, these fires are not normally destructive, because natural ignitions occur frequently enough to keep fuels to a minimum (Greenlee et. al. 1979). The point is that nature has already worked out the allowable burn acreage for us. If we alter this naturally-determined allowable burn acreage, we alter the character of the fires that occur, and we often alter the vegetation through type conversion.

The most logical allowable burn acreage figure, then, would be one that uses the natural fire cycles for the vegetation types concerned as the prime factor. In this interpretation the allowable burn acreage is the acreage that would burn in a given time period if the natural burn cycle was reinstated. This modern allowable burn acreage, however, would be independent of the cause of ignition (natural, planned, or accidental).

Several qualifications need to be made at this point: First, since suppression has been practiced for a number of years, there is a problem of transition to a natural fire periodicity. Second, natural fire periodicity is not a fixed value, but is a value that varies in space and in time. One vegetation type has a differing periodicity of burning than another, and that vegetation type may experience variations in the periods between fires that exceeds the variation between vegetation types. Third, the natural periodicity of fire cannot be used as a guide in every case. One exmaple is the coastal redwood region, where natural fire periodicity may exceed two hundred years. Despite these reservations, the natural fire periodicity is a viable management tool that can serve as a useful guide to fire management.

How can this concept be employed as a management tool? First, the fire regime must be determined for each major vegetation type. The amount of literature on this subject is growing. Southern California chaparral and grass burn on a natural cycle of 10-40 years (Muller et. al. 1968) and 1-5 years respectively. Oak woodlands and forests have more variable natural fire cycles, the variation corresponding to slope, aspect, elevation, latitude, ignition sources, and moisture. The range for forests appears to be from 8 years for lower Sierran coniferous forests (Van Wagtendonk 1975), to 200-300 years for coastal redwood (Greenlee, paper in preparation).

This variability for vegetation other than grass and chaparral makes field investigation of fire scars necessary (Arno and Sneck 1977). Fire atlases are not useful in this work, as the fires recorded in the recent past are almost always strongly affected by suppression efforts. Fire scars can commonly be found that will date fires from 1700 to 1900. These scars will include fires caused by Aboriginal Americans, and this inclusion of Aboriginal ignitions is generally accepted as a factor in the fire regime that developed the ecology and fuel dynamics of the Sierra.

When fire frequencies over a large period of time before 1900 are known, either by field work or by literature searches[1], then that frequency should be converted to the number of acres burned in fifty years. For example, if the average cycle on a 1000 acre tract of ponderosa pine from 1700 to 1900 was twenty years, then an average of 2500 acres on that tract burned every fifty years. These fires will include natural, deliberate, and accidental ignitions.

If mixes of vegetation with different fire cycles are found in the same fire management area, then the different fire cycles would determine a range in allowable burn acreages.

Fuel Management Planning--Key to the Future

Consideration of the role of fuel modification in the integrated fire management plan focused on large scale fuel reduction through physical manipulation and on fuel break construction. A great deal of the actual work in fuel modification being done on forests today is in conjunction with, and paid by, timber operations.

1. Identifying areas that need fuel reduction.

   Fuel modification is the real key to dollar savings in the long run in fire management. Prescribed burning is gaining in popularity as a modification tool as the savings become more apparent.

[1] A literature search for fire history information can be done by contacting the FIREBASE system at Firebase Access Center, P.O. Box 245, Berkeley, California 94701 (415) 486-3688 and asking for searches of the terms "fire frequency" and "fire histories".

The fire modelling was used to help evaluate which areas needed fuel modification. Priorities for fuel reduction work were made by 1) selecting those areas where fuel inventories show an unacceptable load of fuel, and 2) ranking these areas in order of total resource value per acre.

2. Identifying Priorities for Fuel Break Construction

The controversy on fuel modification presently centers on fuel break construction. Harrison et. al. (1973) found in a modelling study that the savings incurred by expanding present fuel breaks and building new fuel breaks in Southern California outweighed the additional costs. These authors claim that, in their specific area near Ojai, expanded fuel breaks eliminated fires over 20,000 acres. Omi (1977), in a study of historical fires on the Angeles National Forest, casts doubt on these claims. He found that some areas of the forest "lacked sufficient data", implying that no secondary fuel breaks were needed. Omi's work further indicated that secondary breaks apparently had no effect on fire sizes, although they do have other benefits, such as access for suppression and for prescribed burning. Finally, some primary breaks did the job and some did not. One difference between Omi's study and others is that Omi correctly used a wide range of burning conditions in his modelling.

The proposed process to obtain fuel break construction priorities used the modelling technique. In this process, the costs of suppression in the original fires modelled (without fuel breaks) were compared to the costs of fires modelled a second time with fuel breaks. These new models used the same points of origin and fuel and weather conditions as the first set of models. The total value of benefits-minus-costs of the new models was added to the cost of fuel break construction and this total was added to the total costs of the first set of models. If fuel break construction reduced costs, then that fuel break was given a high priority. Refer to the fire management plan that follows for an example of this process in use.

Managing Fires in Wilderness Areas

Before national forests were established, natural fires were prevalent in many areas, particularly in high elevations. In the early part of this century indiscriminate burning by white settlers led to a suppression policy. This policy was inconsistent in wilderness areas because the Wilderness Act states wilderness should be "protected and managed so as to preserve its natural conditions".

A precedent has now been set in the Park Service and Forest Service

The fire modelling was used to help evaluate which areas needed fuel modification. Priorities for fuel reduction work were made by 1) selecting those areas where fuel inventories show an unacceptable load of fuel, and 2) ranking these areas in order of total resource value per acre.

2. Identifying Priorities for Fuel Break Construction

The controversy on fuel modification presently centers on fuel break construction. Harrison et. al. (1973) found in a modelling study that the savings incurred by expanding present fuel breaks and building new fuel breaks in Southern California outweighed the additional costs. These authors claim that, in their specific area near Ojai, expanded fuel breaks eliminated fires over 20,000 acres. Omi (1977), in a study of historical fires on the Angeles National Forest, casts doubt on these claims. He found that some areas of the forest "lacked sufficient data", implying that no secondary fuel breaks were needed. Omi's work further indicated that secondary breaks apparently had no effect on fire sizes, although they do have other benefits, such as access for suppression and for prescribed burning. Finally, some primary breaks did the job and some did not. One difference between Omi's study and others is that Omi correctly used a wide range of burning conditions in his modelling.

The proposed process to obtain fuel break construction priorities used the modelling technique. In this process, the costs of suppression in the original fires modelled (without fuel breaks) were compared to the costs of fires modelled a second time with fuel breaks. These new models used the same points of origin and fuel and weather conditions as the first set of models. The total value of benefits-minus-costs of the new models was added to the cost of fuel break construction and this total was added to the total costs of the first set of models. If fuel break construction reduced costs, then that fuel break was given a high priority. Refer to the fire management plan that follows for an example of this process in use.

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to allow natural fire back into the wilderness areas. In California, the Park Service is allowing natural fires to burn in designated zones of Sequoia, King's Canyon, and Yosemite National Parks. Throughout the country, the Forest Service is experimenting with the same policy. Natural fire management has been used in the Selway-Bitterroot Wilderness in Idaho, the Gila Wilderness in Arizona, and in the Emigrant Basin Wilderness in California. Allowing natural fires to burn has resulted in net savings to the fire management budget of Sequoia and King's Canyon National Parks (Omi et. al. 1975).

Certain restraints are to be noted. Congress still allows normal suppression activity when it is deemed necessary in wilderness areas (Udall et. al. 1978). In addition, policy indicates that human life and property should be protected, fire should not be allowed to cross wilderness boundaries, and only lighting fires should be allowed to burn.

Due to the success of these wilderness policies in experimental areas, more wilderness areas should be put into natural fire management. The Park Service is now moving their natural fire boundaries downward in elevation and out of wilderness areas in an effort to bring the natural role of fire back into parks. This effort should be closely watched, as it addresses the ultimate means of saving fire management dollars (Omi et. al. 1975). Of course, adequate fuel management is necessary prior to such a move in much of the Forest Service-controlled land.

The process of selecting areas for wilderness fire management can be aided by the use of fire modelling. Models can indicate how large fires could become, which portions of the wilderness boundaries may be breached by fires within, and whether fuel modification may be needed near or, if policy permits, within the boundary.

A Way to Find the Best Mix of Management Activities

Fire managers should allocate their budgets to the various fire management activities (detection, initial attack, prevention, fuel management, and natural fire management) so that a cost-effective combination of activity levels is utilized. The best criterion of success in such an effort would be the maximization of benefits-minus-costs.

This optimization problem lends itself well to marginal analysis, except, again, there is a problem with production functions, especially with prevention and detection. In this study, no effort was made to generate production functions for prevention or detection. The optimization model used to get the best mix of suppression,

initial attack, and fuel modification dollars is the system based around FOCUS that is discussed above.

The greatest problem with determining the best mix lies in the administrative area: the old emergency fund principle of opening the purse only when conflagrations occur. This policy is preventing the use of enough presuppression dollars for fuel modification (Kourtz 1972). As indicated above, the authors contend that the non-suppression dollars are going to result in real savings in the long-run.

Another snag recently appeared in an unusual decision that Congress would determine the dollar allocations to each fire management activity. Presumably, this practice will be discontinued as soon as viable processes are developed for allocating dollars.

Assumptions

In the course of this study, it was necessary to make a number of assumptions. Some of the most important are:

* Costs of fuelbreak construction, fuel modification, and suppression are derived from district experience and from U.S.F.S. form FSH11/78 R-5, Supp. 26.

* Fire modelling is based on current technology, primarily the essentially untested nomograms developed by Frank Albini (1976).

* To the extent that FOCUS is used, its assumptions apply.

* Weather conditions were not based on a probabilistic or variance-based model, but were derived from 90th and 50th percentile fire weather conditions.

* Resource values were adopted from the Resource Planning Act. As is recognized by those who use them these values need improvement.

* Timing of various impacts, expenses, and benefits is ignored, and all costs and benefits are present value.

* Suppression modelling relies on certain assumptions concerning availability of forces and timing of arrival. A simple model was constructed to assertain the probability of containment.

If the process is selected for further development, these assump-

tions should be evaluated. Particular attention should be given to fire economics studies presently underway, including those under the leadership of Tom Mills at the U.S. Forest Service Riverside Fire Lab (Mills 1978), and those being done by Julie and Ross Gorte (Gorte and Gorte 1977). Bernie Armstrong at Sequoia National Forest headquarters can provide valuable input concerning probabilistic models that, for simplicity, were not used by the authors.

Suppression modelling by hand has certain disadvantages (Harrison et. al. 1973). Modelling by hand takes time, so only a few fires can be modelled. The effect of uncertainties in incidence location and of fire weather persistance is hard to determine.

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